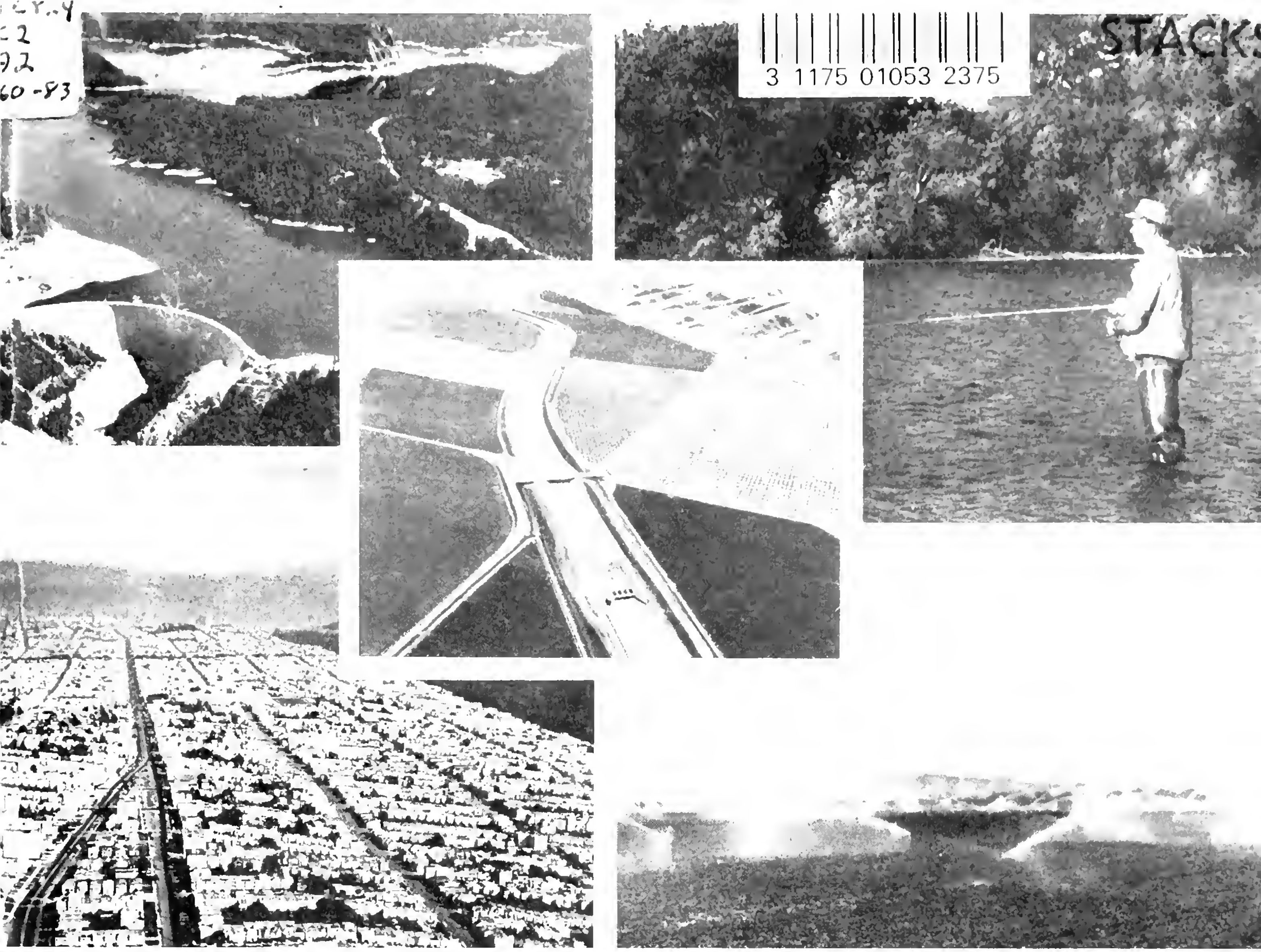
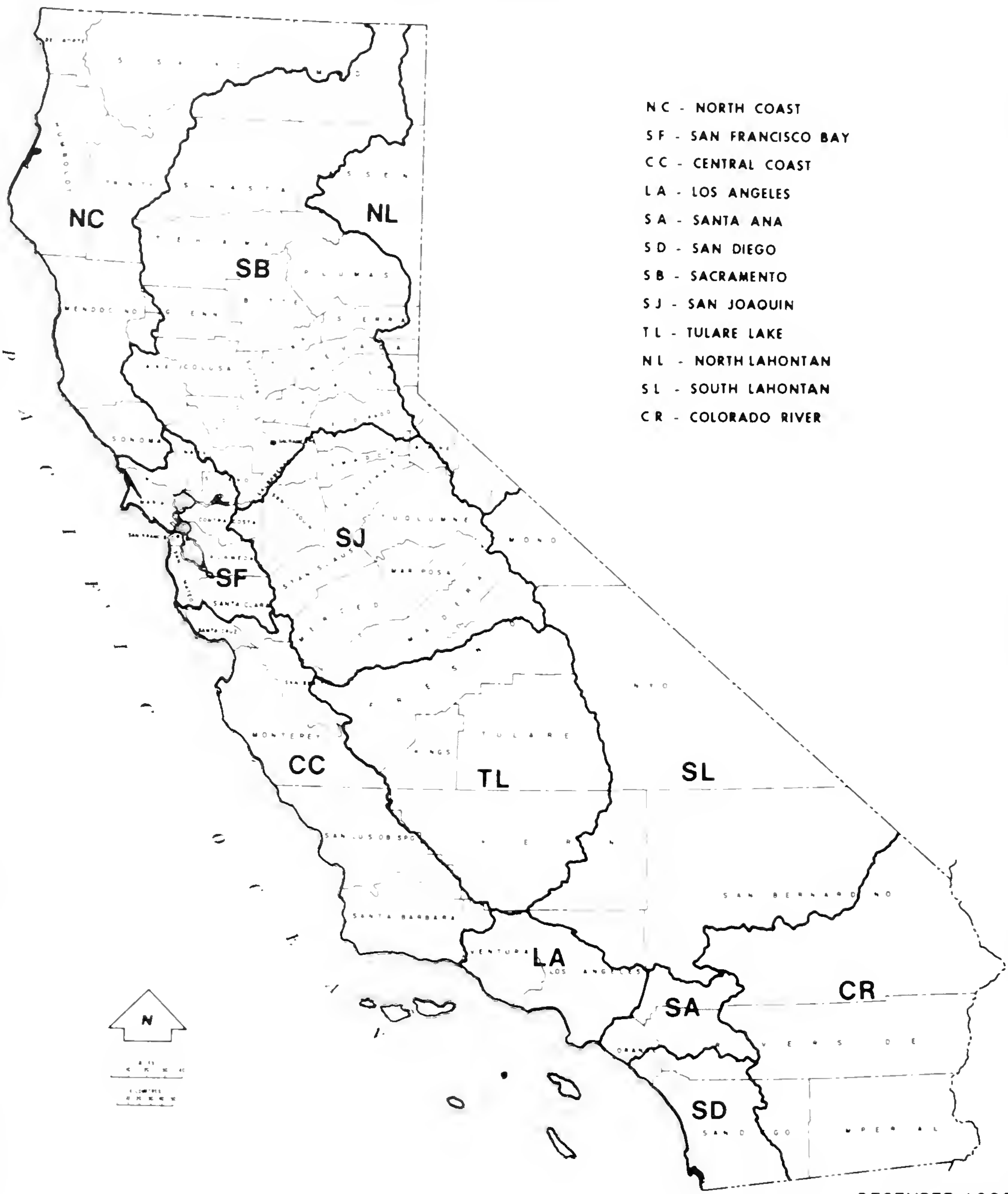


The California Water Plan

Projected Use and Available Water Supplies to 2010

Bulletin 160-83
December 1983

HYDROLOGIC STUDY AREAS OF CALIFORNIA



DECEMBER 1982

Department of
Water Resources

Bulletin 160-83

The California Water Plan

Projected Use and Available Water Supplies to 2010

December 1983

Gordon K. Van Vleck
Secretary for Resources

The Resources Agency

George Deukmejian
Governor

State of California

David N. Kennedy
Director

Department of Water Resources

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ON THE COVER: The California Water Plan comprises the use, control, protection, conservation, and development of California's water resources. These scenes represent the central aspect of the plan, the transfer of surplus water from areas of origin to satisfy the needs of agriculture and cities in water-deficient areas.

FOREWORD

This is the fourth in the 160 series of bulletins that contribute to the updating of the California Water Plan. It presents information on amounts of water currently used in the State, projects water uses to 2010, and identifies some of the alternative sources of supplies or potential shortages associated with those future uses. It is essentially a technical report, representing some four years of intensive effort by the Department's land and water use analysts, economists, and engineers.

Since 1974, when the last report in this series was published, urban and agricultural uses of water have increased steadily, and increases by both sectors are seen as continuing to grow over the next 30 years. Water conservation and waste water reclamation can and will help to meet future water needs by extending the use of presently developed supplies. Efforts to conserve water are projected to reduce needs by 1.6 million acre-feet in 2010. Use of reclaimed water is also expected to increase.

Trends indicate that the State's population will be 11 million greater in 2010, thus increasing total urban net water use by about 37 percent. The projected addition of 700,000 acres of irrigated farmland by 2010 is expected to increase total agricultural net water use by about 6 percent. Most of the expansion in acreage will occur in the Central Valley, where use in the Sacramento Valley will grow by 15 percent and in the San Joaquin River basin, by 10 percent. In the Tulare Lake basin, where 90 percent of the irrigable land overlying usable ground water is already developed, water use is projected to increase by only 6 percent.

In all but a few local areas of the State, available water supplies are sufficient to meet current water needs at the 1980 level of development. However, delays encountered in constructing needed projects could cause widespread difficulties in the future. A series of drought years could also create difficulty because the present margin of safety narrows as water needs increase. Ground water overdraft, especially in the San Joaquin Valley, will continue to worsen until surplus Sacramento River water can be imported.

Generally speaking, the projections in the report indicate considerably less population growth for California than did the initial report in this series, published in 1966. However, the growth that is taking place and the current projections for growth over the next 30 years indicate that further development of water facilities will be necessary to meet the State's urban and agricultural water needs. Recommended actions for these facilities will be the subject of other Department reports.

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CONTENTS

CONTENTS (Continued)

CONTENTS (Continued)

CONTENTS (Continued)

CONTENTS (Continued)

Sidebars

CONTENTS (Continued)

Figures

CONTENTS (Continued)

Figures (Continued)

CONTENTS (Continued)

Figures (Continued)

Tables

CONTENTS (Continued)

Tables (Continued)

Plates

ACKNOWLEDGMENTS FOR PHOTOGRAPHS

Page	*Source*
7	California State Library
11	Department of Water Resources (DWR) Negative 4546-17
12	DWR 830-25 (left), 1032-69 (right)
13	DWR 6139-1
14	DWR 3896-26
15	DWR 3896-25
21	DWR 3385-18
28	National Aeronautics and Space Administration
30	DWR 6112-33
41	DWR 6112-39
50	DWR 4947-126
53	National Aeronautics and Space Administration
55	DWR 4521-6
56	California Department of Fish and Game
75	DWR 6139-77
118	DWR 6139-76
125	DWR 6139-91
134	DWR 6139-58
136	DWR 6139-92
141	U.S. Soil Conservation Service
142	DWR 6139-94 (upper), 6139-95 (lower)
143	DWR 6139-78
146	DWR 6139-96
147	DWR 6139-79
150	DWR 6139-74
153	DWR 6139-54
155	DWR 6139-12 (left), 4515-6 (right)
158	DWR 4947-21
159	DWR 6139-23
161	DWR 3811-1
163	DWR 6139-97
166	U.S. Soil Conservation Service
168	U.S. Soil Conservation Service
177	DWR 4142-3
181	U.S. Bureau of Reclamation
182	Western Aerial Photos, Redwood City, Calif.
183	DWR 5435-26
187	U.S. Bureau of Reclamation
191	DWR 4497-41
194	DWR 5233-28
200	DWR 6139-82
204	DWR 6112-22
208	DWR 6139-81
216	Los Angeles Times
220	DWR 6112-19
222	DWR 6139-73
226	DWR 6139-80
230	DWR 6139-7
232	DWR 6139-98
236	DWR 6139-4
240	DWR 3645-28
244	U.S. Soil Conservation Service
252	The Metropolitan Water District of Southern California

CHAPTER I

SUMMARY AND FINDINGS

Since publishing *The California Water Plan* (Bulletin 3) in 1957, the Department of Water Resources has issued a series of reports that update certain elements of the plan. This report (Bulletin 160-83) is the fourth in that series. It describes in detail the current water use and supply situation (1980); presents an up-to-date appraisal of statewide water uses for various beneficial purposes throughout the State in 1990, 2000, and 2010; and identifies potential sources of water supplies to satisfy those uses. It also describes key events and accomplishments in water planning and development of the State's water resources.

The Bulletin 160 series is designed to present the overall outlook for water supply needs throughout the State and to assess the availability of water supplies to satisfy these needs. The series presents basic information for those who are interested in water matters in California and provides a framework for water managers and the Legislature in making water management decisions. Rather than serving as a blueprint for specific water management actions, these reports emphasize the relationship between water supplies and expected changes in the agricultural, urban, instream, and other beneficial uses of the resource.

While the basic scope of these reports has remained essentially unchanged, each has had some distinguishing characteristic reflecting attitudes and emphasis at the time of its publication. Bulletin 160-66 emphasized implementation of the California Water Plan. Bulletin 160-70 modified the outlook of earlier reports by recognizing a slowdown in the State's population growth and reflected this with a statement that the need for additional water facilities for the State Water Project could be delayed beyond the date previously projected. Bulletin 160-74 departed from the earlier practice of developing a single forecast of future water use by presenting four different scenarios as to future conditions and events that affect water use.

This update compares water use and water supplies and provides additional information on the planning process conducted by the Department. As such, it is more of a "user's manual" than previous editions have been. As part of this process, agricultural models were developed and applied for the first time. Although much remains to be done to improve the models, they were especially helpful in assessing the general economic effects of increasing water and energy costs. The report quantifies the effect of urban and agricultural water conservation measures and the potential for water reclamation as a means of reducing water needs. Finally, a number of nonstructural options for making more effective use of water supplies, particularly in times of shortage, are proposed for further consideration.

The more important findings, set forth below, summarize concisely the information of significance for which supporting data and other information are presented in detail in the ensuing chapters. Most of the findings and conclusions presented in this report are summarized by Hydrologic Study Area (HSA). The 12 HSAs, which cover all of California, are shown in the map on the inside front cover of this report.

THE BULLETIN 160 SERIES

Bulletin 160-66	*Implementation of the California Water Plan*	March 1966
Bulletin 160-70	*Water for California The California Water Plan Outlook in 1970*	December 1970
Bulletin 160-74	*The California Water Plan Outlook in 1974*	November 1974

Outlook in 1983

In General—

- While available water supplies are generally sufficient to meet current water needs, they include significant ground water overdraft. Delays encountered in developing additional surface water supplies in a timely manner will result in future shortages or increased ground water overdraft until needed projects can be built.
- Service areas of the State Water Project will face increased risk of severe deficiencies in drier years until adequate supplemental supplies are provided. Moreover, without a Delta transfer facility, substantial releases from storage will be required for protection of the Delta and even then will not completely restore the fishery.
- In the San Joaquin Valley, continued expansion of irrigated agriculture must rely on increased use of ground water supplies until additional surface water supplies can be imported.
- Although water conservation and water reclamation will help to delay the need for additional surface water development in some areas, they are by no means sufficient to satisfy the water needs projected to occur during the next 30 years.
- Laws, administrative actions, environmental concerns, public opinion, cost considerations, and other developments of the past two decades have limited new surface water development. As a result, increased attention has been given to nonstructural solutions to water problems.
- Population increase and related economic growth—factors over which there is probably the least influence or control—will have the most significant impact on projected increases in water use.
- Continued urban and agricultural growth and greater attention to instream flows will intensify the competition for California's water resources, necessitating even more prudent management.
- While the quality of surface water throughout the State is generally satisfactory, contamination is threatening ground water in some areas and poses health problems.
- Agricultural problems from insufficient drainage of brackish water in the San Joaquin Valley will progressively worsen, if no increase in remedial actions occurs.

On Growth—

- California's population is expected to increase from 23.8 million in 1980 to 34.4 million in 2010. This amounts to an average annual increase of 340,000, compared to 380,000 annually between 1970 and 1980.
- Projected natural increase in population accounts for more than half, or 5.8 million persons, out of the projected growth of 10.6 million between 1980 and 2010. The total growth assumes a birth rate of 2.1 children per woman of childbearing age and an average annual net in-migration of 150,000.
- The South Coastal region—comprising the Los Angeles, Santa Ana, and San Diego Hydrologic Study Areas—are projected to account for 50 percent of total statewide population growth over the next 30 years.
- Irrigated land acreage is projected to increase from 9.5 million acres in 1980 to 10.2 million acres by 2010. This increase, about 700,000 acres (equal to about 7 percent of the 1980 level), represents a significant slowdown from historical trends, and is, in fact, about the same as that which occurred in the preceding eight years. Most of the increase will occur in the Central Valley, with the Sacramento HSA increasing the most (15 percent), followed by the San Joaquin HSA (10 percent) and the Tulare Lake HSA (6 percent).
- Increases in production cost will continue the trend toward higher value crops, such as cotton, truck crops, and grapes, with a decline in grain and pasture. It appears that California can retain or even improve its competitive marketing position for certain crops because other competing areas in the United States are facing serious water problems.
- Public participation in fresh-water recreation and in fish and wildlife activities is expected to intensify because of growth of population and greater per capita participation in water-related leisure pursuits.

On Water Uses—

- Statewide, net water use is projected to increase from 33.8 million acre-feet in 1980 to 37.3 million acre-feet by 2010. Of this increase, urban use accounts for 1.8 million acre-feet (a 37-percent increase over 1980). This compares to an increase of 1.7 million acre-feet (a 6-percent increase over 1980) for agriculture.

- Total net water use is projected to increase at an average annual rate of 120,000 acre-feet over the next 30 years (1980–2010). This is markedly less than the average annual rate of increase of about 550,000 acre-feet for the previous 30 years (1950–1980).
- The greatest need for additional water supplies exists in the San Joaquin, Tulare Lake, and South Coastal region HSAs. The latter two areas are the principal importers of supplies from the State Water Project.
- Sixty percent of the increase in net urban water use is expected to occur in the coastal metropolitan areas of the San Francisco Bay, Central Coast, Los Angeles, Santa Ana, and San Diego HSAs. About 45 percent or 860,000 acre-feet of this use will take place in the latter three areas, which together make up the South Coastal region.
- The Central Valley (the Sacramento, San Joaquin, and Tulare Lake HSAs) will experience the major increase in agricultural net water use. The San Francisco Bay and South Coastal region HSAs are projected to have decreases in agricultural net water use.
  - The principal increase in annual net water use by 2010 is 700,000 acre-feet in the Tulare Lake HSA. This is a 9-percent increase over the 1980 level. If the State Water Project is unable to meet its contract commitments, there will be a shortage of as much as 660,000 acre-feet of dependable surface water supply annually, 90 percent of which could be offset by additional overdraft. In that case, total overdraft may be as much as 2.4 million acre-feet annually by 2010.
  - The projected increase in annual net water use of 480,000 acre-feet by 2010 in the San Joaquin HSA (an 8-percent increase) can be satisfied by use of available dependable surface water supplies of 330,000 acre-feet and increased ground water overdraft of 150,000 acre-feet annually by 2010.
  - The projected increase in annual net water use of 460,000 acre-feet in the Sacramento HSA (a 7-percent increase) can be satisfied by water supplies available within that area.
- In the Colorado River HSA, increased irrigation efficiency and water conserved by reducing the amount of water lost as outflow to the Salton Sea could allow increased agricultural production. It may be possible to transfer the conserved water to the South Coastal region.
- Net water use associated with public wildlife management areas, nonurban public parks, and energy production is forecast to increase annually from 710,000 acre-feet in 1980 to 900,000 acre-feet in 2010, for a 30-percent or 190,000-acre-foot increase. Statewide demand for instream flows was not evaluated separately.
- Overall, higher costs of energy, labor, and other production elements are expected to increase irrigation efficiencies, thereby reducing applied water in 2010 by about 3.5 million acre-feet, a greater reduction than would otherwise have been projected. The corresponding reduction in the need for additional water supplies, however, is only 645,000 acre-feet because of reuse of excess applied water.
- Reduction in additional water supply needs due to expected urban water conservation measures is projected to amount to 70 percent of resultant reductions in applied water in 2010 (950,000 acre-feet out of 1.4 million acre-feet).
- Increased irrigation efficiency could save considerable energy. Annual savings of 400 million kilowatthours are forecast in the Central Valley for 2010.

On Present Water Supplies—

- California's present water needs are being met by existing State, federal, and local projects, and, in some areas, especially the San Joaquin Valley, by overdrafting ground water supplies. More water is available from the existing projects than is being used now, and this reserve could be used to satisfy increasing needs for a number of years, or alleviate existing overdraft, if ncessary conveyance facilities were constructed in a timely manner. One such facility is the Mid-Valley Canal, which would convey water to the San Joaquin and Tulare Lake HSAs.
- Supplemental water needs currently average 1.8 million acre-feet per year. These needs are being met primarily through ground water overdraft. The major overdrafted areas are situated in the San Joaquin, Tulare Lake, and Central Coast HSAs.
- Total overdraft of ground water basins has decreased in the past eight years by about 80,000 acre-feet per year, primarily because of new water brought into the western San Joaquin Valley by the State Water Project and the San Luis Division of the Central Valley Project, thus replacing to some extent previ-

ous ground water use. Remaining overdrafts are not considered permanent sources of water supply.

- Intentionally reclaimed waste water furnished about 250,000 acre-feet of usable water supply in 1980, most of which was used for irrigation of crops and landscaping. An additional 610,000 acre-feet of waste water was indirectly reclaimed, returned to the surface and ground water supply, and reused.
- The following major surface water supply projects have been built since 1974:
- Hidden Dam on the Fresno River, Buchanan Dam on the Chowchilla River, and New Melones Dam on the Stanislaus River, constructed by the U. S. Army Corps of Engineers and integrated into the Central Valley Project. Warm Springs Dam on Dry Creek, a tributary of the Russian River, scheduled for completion by the Corps in 1984, will provide water for Sonoma and Marin Counties.

  Indian Valley Dam on the North Fork Cache Creek, built by the Yolo County Flood Control and Water Conservation District to provide water for irrigation in Yolo County.
- Soulajule Dam, built and operated by the Marin Municipal Water district for municipal water supply.

On Future Water Supplies—

- Only about 5.5 million acre-feet, out of a total remaining undeveloped statewide surface water resource of 47.9 million acre-feet, appears to be potentially developable, considering current uses; wild and scenic river designations; and geologic, economic, and other constraints. Of this potential source, 4.6 million acre-feet, or 84 percent, occurs within the Sacramento Valley.
- Upstream depletions will reduce the present yield of the existing State Water Project facilities from 2.3 million acre-feet annually to about 1.7 million acre-feet by 2010. These upstream depletions may be offset by savings from conservation, water reclamation, additional pumping capacity at the Delta, construction of the Cottonwood Creek Project, and greater use of underground storage capacity in conjunction with surplus surface supplies. The resulting yield is about 1.5 million acre-feet less than projected requirements. Because of voter rejection of Proposition 9, certain additions to the State Water Project have been eliminated from consideration. Several alternatives exist to eventually make up this deficit, and planning is under way to select the best projects and schedules.
- With currently developed supplies, the State Water Project can satisfy its service area needs in average and wet years during the 1980s. Beyond that period, the projected decreases in yield, coupled with continued growth in requirements, increase the risk of more severe and frequent shortages.
- Total ground water in storage in California amounts to more than 850 million acre-feet. In most areas where shortages in surface supplies are projected, ground water is available within economic pumping lifts and can be used as a supplemental supply until surface supplies become available.

Organization and Scope of Report

Each chapter in this report is intended to consider a particular aspect of long-range water planning. While future water needs and the availability of water to meet those needs is the central focus of the report, these aspects must be viewed in the context of legislation and events influencing water management. Consequently, the reader will find background information in the first part of the report, including those significant events and planning considerations that not only influence water management decisions but also affect projections of future water needs. The report concludes with a general summation of the water situation facing California and a recognition of some matters that are not fully reflected in this report but that are likely to influence water management in the future.

Earlier editions of the Bulletin 160 series were based on similar areas, for the most part, but there are some significant differences. Specifically, compared to Bulletin 160-74, the western boundary between the San Joaquin and Tulare Lake HSAs has been shifted northward somewhat; the Delta-Central Sierra HSA has been eliminated and the area split between the Sacramento and San Joaquin HSAs; the Russian River drainage area has been transferred from the San Francisco HSA to the North Coast HSA; and the South Coast HSA has been divided into three parts, namely, the Los Angeles, Santa Ana, and San Diego HSAs.

This restructuring of areas has come about as a result of a cooperative effort by the Department of Water Resources, the State Water Resources Control Board, and the U. S. Geological Survey to estab-

lish boundaries each agency could use for data and study summaries, thereby providing for more efficient exchange of information.

Planning for Water Resources Development (Chapter II)

The publication of the Bulletin 160 series of reports has extended over a sufficient number of years to permit development of a "track record." Chapter II looks at that record. It contains charts showing population, irrigated land, and net water use over several decades. Of particular interest is the comparison of the 1980 "actuals" with some of the earlier trend line projections for that year. On the record, the Department has not consistently erred, overall, on either the high or low side. The tendency has been to overestimate population growth and underestimate agricultural development. There are, however, exceptions to even this generalization. The 1980 census showed that California grew more rapidly in the last decade than was anticipated during the 1970s. In some areas, in fact, the 1980 population proved to be larger than that projected for 1990.

Chapter II also presents a brief history of water planning and development in California and describes the conditions that have made such work necessary, including geographic and climatic factors. Not only are the most agriculturally productive areas of the State climatically arid or semi-arid, but most of the urban growth has occurred outside the "water-rich" areas of the State. Consequently, both agricultural and urban growth have created enormous pressure to develop and transport the resource. That pressure, however, is not necessarily compatible with other water uses, and therein lies the basis for the continuing debate regarding ways to best manage water supplies.

The chapter also includes a description of the severe drought of 1976 and 1977 and the ways in which California coped with its effects.

Water Use and Water Supply in 1980 (Chapter III)

Probably the most complete presentation of the Department's involvement in water planning yet appearing in the Bulletin 160 series is presented in Chapter III, which is an information base for water use and water supply in 1980. Both procedural and factual, it contains present (1980) data on those factors affecting water use projections. Significant information is presented which is intended as a take-off point for the projections described in Chapters IV and V.

Chapter III describes the Department's land use surveys and satellite surveillance programs. From these programs, the Department can determine how much irrigated crop acreage there is by type and where it is located. Likewise, on-ground measurements and surveys provide necessary water use information. These data are basic to long-range water planning. Chapter III also explains net water use and its relationship to applied water, evapotranspiration, and the potential for water savings. It also contains a brief discussion of irrigation systems and other factors affecting water conservation. Rice and alfalfa are big water users and, as noted in the report, have a story of their own.

Chapter III includes a discussion of fish and wildlife resources in the State, including the effects of water development on these resources. A summary of water supplies presented in the last half of the chapter identifies the more significant dams (and reservoirs) and conveyance facilities within the State. The ground water situation is discussed and its management in conjunction with surface water supplies is considered. Energy use and water cost data are also presented. These latter two considerations have received considerable attention since the oil embargo of 1972 and the general increase in the cost of building new water facilities. Their inclusion in this report reflects the Department's recognition of their increased importance in assessing water use, and both were included as specific variables in the models used to assist in the projection of agricultural water use presented in Chapter IV.

An understanding of the State's water problems and management options requires a knowledge of the hydrologic balance—the relationship between water use and water supplies. "The Hydrologic Balance Network for California, 1980," Figure 27, depicts the statewide water network, tracing the uses of water supplies from their source. From this overview, the last portion of the chapter discusses and shows in some detail the sources and disbursement of water for each of the Hydrologic Study Areas in California.

Future Water Use—1980 to 2010 (Chapter IV)

The outlook for future water use in California is presented in Chapter IV. When combined with the water supply considerations presented in Chapter V, it forms the basis for taking specific actions to alleviate any shortfall between developed supplies and future use. Chapter IV also provides a basis for determining the effectiveness of any particular measure, or combination of measures, to meet water supply deficiencies.

Chapter IV is an extension of the planning considerations, data sources, and methodologies described in Chapter III. All the thought and work associated with Chapter IV are designed to produce one key finding: total net water use. The thought process and considerations which lie behind that finding are presented in some detail. The assumptions behind the

agricultural water use projections, for example, concern the derivation of irrigated acreage, appropriate rates of evapotranspiration of water by each crop type, and projections of irrigation efficiency. On the urban side, birth rates and net migration assumptions are presented as a basis for the population projections. Factors affecting per capita water use are presented, including water conservation measures. The chapter also presents net water uses associated with power plant cooling, enhanced oil recovery, recreation, and wildlife habitat.

At least two aspects of the projections appearing in this report distinguish it from previous reports in the Bulletin 160 series. The first is an explicit attempt to account for water savings resulting from conservation. The reader will find a fairly complete discussion of water conservation measures and actions and their impact on the need for water supplies.

A second aspect includes the use of economic models to assist in the projection of agricultural water use. Upon the recommendation of an economic advisory group, the Department began work on this task in 1979. The principal results of this effort included an analysis of California's feed and forage industry, using a linear programming model, and a similar but larger model for all major crops grown in the Central Valley. These models allowed the Department to evaluate directly the impact of water costs on agricultural acreage, particularly the often-raised issue of agriculture's future in relation to increasing water costs.

In summary, Chapter IV represents the Department's best forecast of future water use levels for the State as a whole, as well as by regions within the State. The major variables affecting those projections are presented. The findings in this chapter, combined with the water supply considerations presented in Chapter V, establish a basis for assessing water management options and their urgency.

Projected Use of Water Supplies to 2010 (Chapter V)

As the title suggests, Chapter V emphasizes water supplies. It assesses the ways and means of meeting future water needs. Conservation is reflected in the estimates of net water use presented in Chapter IV. The need for additional water supplies discussed in this chapter is measured against the reduced level of use created by conservation.

Chapter V contains two major sections: (1) a general or statewide treatment of water supplies and (2) regional discussions that compare supplies with uses by decade from 1980 to 2010. In the first section, one of the most telling displays shows the remaining developable surface water in California, as limited by current priorities for use and other constraints. In addition, water supplies, as they relate to the State Water Project and the Central Valley Project, are discussed in some detail. The reader may find the comparison of water supplies and requirements on the SWP particularly relevant. The SWP is looked to as a supply for most of the additional urban water requirements. Without additional supplies, the ability of the existing facilities to meet contractual commitments decreases because of growth in both the import and the upstream areas. The latter, referred to as areas of origin, have first call on the resource.

To round out the statewide discussion of water supplies, Chapter V identifies major existing and potential local projects, waste water reclamation possibilities, and ground water availability and use. As noted previously, cost considerations have taken on added importance, particularly as they relate to ground water and the cost of pumping. Agriculture, especially, is sensitive to significant increases in the cost of obtaining ground water.

Chapter V concludes with a series of Hydrologic Study Area summaries and, in that respect, is an extension of the last half of Chapter III. Insights into those key conditions affecting water management decisions in each area are highlighted, as are the issues and management problems expected to exist in coming decades.

Options for the Future (Chapter VI)

Finally, Chapter VI draws from earlier chapters, particularly Chapters IV and V, and discusses some of the options available to meet indicated water needs over the next 30 years. The chapter presents a concise summary of the present water supply situation, statewide and by region. This is followed by a discussion of potential water supply sources, including surface and ground water, conjunctive use possibilities, water reclamation, water transfers, and other nonstructural water management options. Chapter VI concludes with a discussion of some of the factors that will ultimately decide which solutions receive greatest emphasis and the respective roles of agencies responsible for their implementation.

CHAPTER II

PLANNING FOR WATER RESOURCES DEVELOPMENT

Water resources planning and development in California has a long and often complex history that dates back to the late 18th century. This chapter reviews the more notable events that have occurred, with emphasis on the California Water Plan and the modifications it has undergone. It presents the historical growth in water storage facilities and compares the projections of population and water use (prepared for planning in anticipation of future water needs) published in the 1966, 1970, and 1974 updates of the California Water Plan. An understanding of California's geography and climate is basic to a discussion of water in California. The maps and text in Figure 1 review California's geography and climate and their profound impact on water problems.

Early Planning and Development

The earliest instances of the development of California's water resources occurred at the Spanish missions in the last three decades of the 18th century. Already familiar with the arid conditions in Baja California, the Franciscan fathers tended to establish their mission settlements in Alta California where water for irrigation was most readily available. Although some cultivation by Indians had taken place along the Colorado River, the history of irrigated agriculture in California really began with the mission gardens and fields fed by streams that were dammed and diverted through canals. The missions were forced out of operation under Mexican rule in the 1830s, and many of them eventually fell to ruins, but their irrigation works set an example for the incoming American and European settlers who were not accustomed to California's long, rainless summers.

After the mission era ended, little was done to develop water until the mid-19th century when California erupted with the frenzy of the gold rush. The miners that thronged by the tens of thousands over the foothills of the Sierra Nevada soon discovered that water was the most effective instrument for unlocking the riches they sought. They built reservoirs and widespread networks of ditches and flumes to divert water from streams at higher elevations and sluice the gold-bearing deposits. These were California's first major hydraulic engineering works. By the mid-1860s, more than 4,000 miles of mining canals and ditches were in operation.

Flumes built during California's gold rush brought water to the miners' sluice boxes at placer mining sites.

MEAN ANNUAL PRECIPITATION

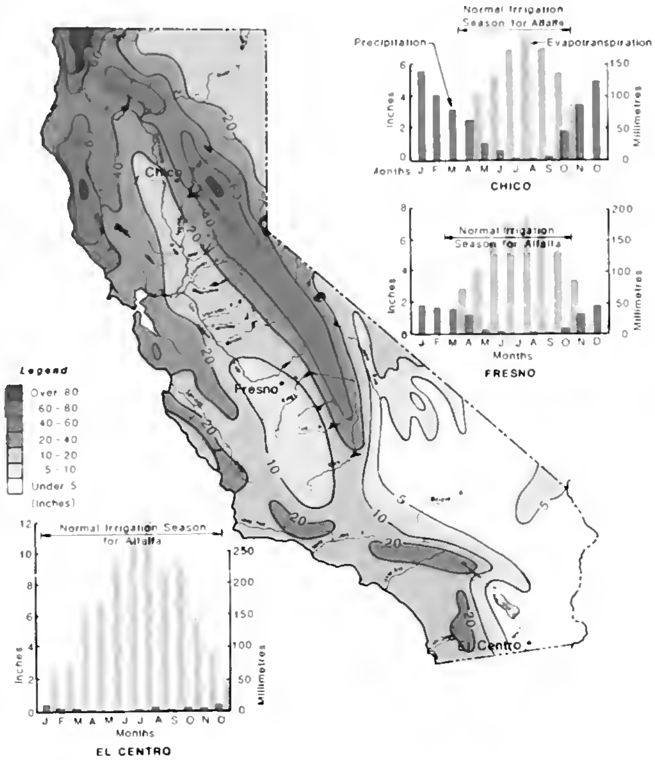


FIGURE 1—CALIFORNIA'S GEOGRAPHY—THE KEY

California is a land of contrasts. Both the highest and the lowest elevations in the contiguous 48 states are situated in California's 100 million acres. The climate ranges from desert to alpine, with average annual precipitation that varies from less than 2 inches to more than 100 inches. California's variation in precipitation is shown on the map at upper left.

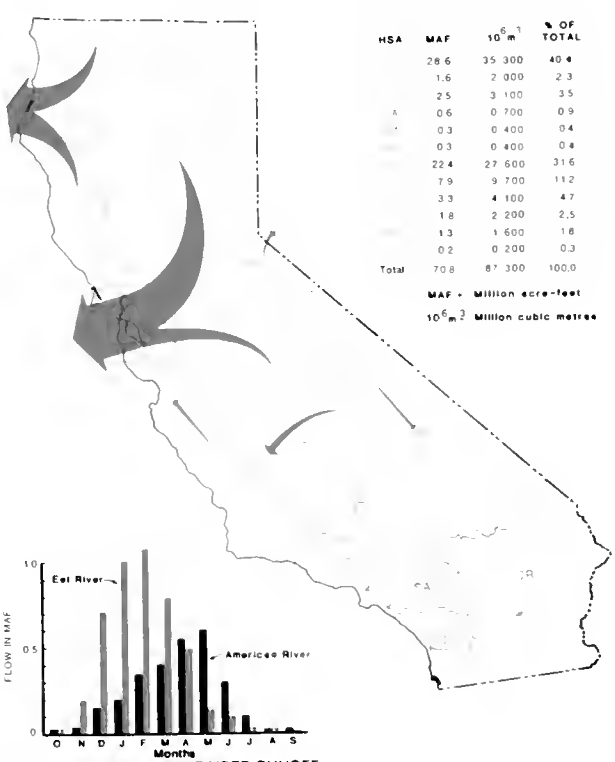
California has warm, dry summers and cool, wet winters. Nearly all the rain and snow occurs in the five winter months—November through March—with practically none during the summer growing season. Fortunately, considerable precipitation occurs as snow at the higher elevations, sustaining the flow of many streams into early summer (see bar graph on map at lower left). The frequency precipitation is highly variable from year to year, including dry periods that have persisted from one to several years. A recent reminder of this fact occurred in 1976 and 1977, the driest two consecutive years ever recorded in California. The longest drought since flow measurements began persisted from 1928 to 1934. However, studies of tree rings conducted by the University of Arizona indicate that California and the western United States have experienced even longer and more severe dry periods.

Those studies also indicate that, in the last 200 years, dry periods occurred from 1760 and 1820 and again from about 1860 to 1880. While tree ring studies provide only a general indication of trend, evidence suggests that both of these periods had less annual rainfall than fell during the 1928–1934 drought upon which California's largest water projects are based. Thus, our developed water supplies may not be as dependable as presently believed.

Average yearly statewide precipitation amounts to 193 million acre-feet. Under natural conditions (that is, excluding the effects of human activities), about 65 percent of this amount is taken up through evaporation and transpiration by trees, plants, and other native vegetation. The remainder, 71 million acre-feet, makes up the long-term average annual statewide runoff. Annual runoff has ranged, however, from as little as 15 million acre-feet in 1976–77 to more than 135 million acre-feet in 1982–83. California's mean annual unimpaired runoff by region is depicted on map at lower left.

The water supply situation is further complicated by the uneven pattern of precipitation. About 70 percent of the State's total precipitation—both rain and snow—occurs in the northern third of the State. However, the use of water is just the reverse—more than 80 percent occurs in the southern two-thirds of the State. Total streamflow is abundant, but it is poorly distributed in place and time to meet needs. Most of the population lives near the coast in large cities that are remote from adequate natural water supplies. A large part of the highly productive agricultural developments are located in arid and semiarid regions where

MEAN ANNUAL UNIMPAIRED RUNOFF



HSA	MAF	$10^6 m^3$	% OF TOTAL
	28 6	35 300	40 4
	1.6	2 000	2 3
	2 5	3 100	3 5
	0 6	0 700	0 9
	0 3	0 400	0 4
	0 3	0 400	0 4
	22 4	27 600	31 6
	7 9	9 700	11 2
	3 3	4 100	4 7
	1 8	2 200	2.5
	1 3	1 600	1 8
	0 2	0 200	0.3
Total	70 8	87 300	100.0

MAF = Million acre-feet

$10^6 m^3$ Million cubic metres

MEAN ANNUAL UNIMPAIRED RUNOFF

TO UNDERSTANDING THE STATE'S BASIC WATER PROBLEMS

the natural water supply is insufficient to meet irrigation needs. (See bar graphs on map at upper left, for example.) The naturally uneven distribution of water within the State, arising from its regional climatic differences, and the uneven distribution of water throughout the year, has required extensive engineering works to regulate and convey the water to areas where the need has developed. More than 1,200 reservoirs have been built over the years by private effort and public agencies at all levels. Their aim has been to regulate wintertime and wet-year runoff and conserve the supply for use when the natural streamflow is insufficient. While the overall water picture in California is made up of many complex and interrelated problems, the redistribution of water from areas of surplus to areas of deficiency continues to provide the greatest challenge.

California also has an abundance of ground water underlying its alluvial valleys, although in some areas, particularly in the southern San Joaquin Valley, the supply is being depleted by pumping in excess of natural replenishment. Statewide total ground water in storage is about 860 million acre-feet, of which a substantial portion may not be readily usable. Average annual natural replenishment is about 5.8 million acre-feet. Overall, ground water in California is being overdrafted at a rate of about 1.8 million acre-feet annually.

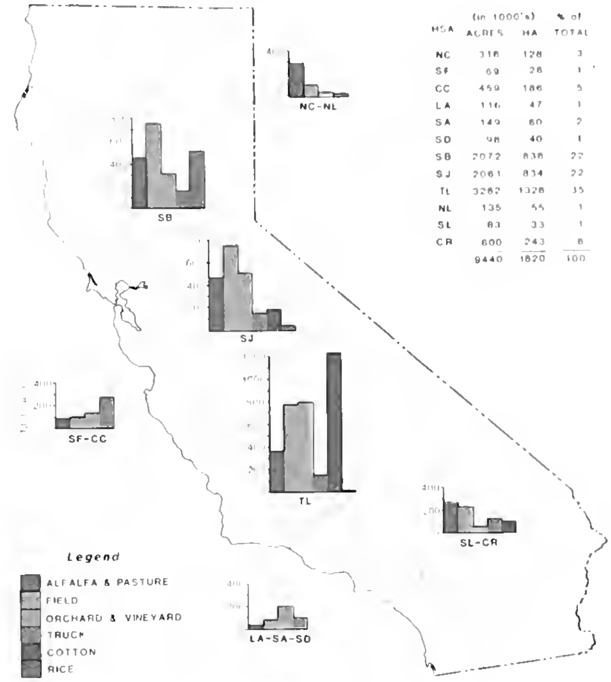
The climate of California favors the growth of most food and fiber crops, including certain crops not grown commercially anywhere else in the nation. Because rainfall for most of California is generally inadequate during the growing season, most crops must be irrigated. Today, 85 percent—28 million acre-feet—of the developed water supplies is used for irrigation of crops. The amount of irrigated land and major crop types are identified on map at upper right.

Forty percent of the water used for irrigation in the State is applied in the Tulare Lake and Colorado River Hydrologic Study Areas. With an average yearly rainfall of less than 10 inches, irrigation water is the lifeblood of farming in these areas.

The Imperial and Coachella Valleys have high-priority rights to water from the Colorado River. Irrigation development in the Tulare Lake Hydrologic Study Area is sustained through an abundant natural and imported water supply and by overdrafting of the ground water basins.

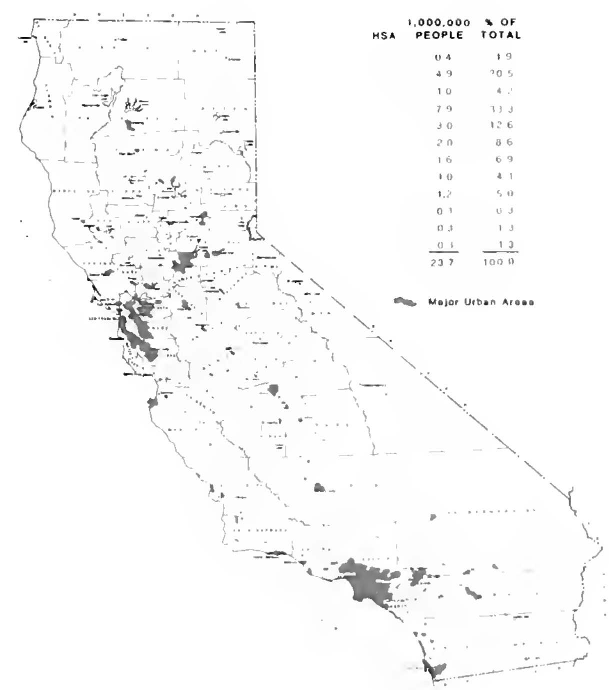
The mild climate of much of Southern California makes the area an appealing place to live, although climate is only one of many reasons for living there. Over half the State's population lives in the south coastal area, as shown on map at lower right. Local water supplies are fully developed, and about 60 percent of the area's needs must be met by importing water.

IRRIGATED LANDS IN 1980



HSA	ACRES (in 1000's)	HA (in 1000's)	% of TOTAL
NC	316	128	3
SF	69	28	1
CC	459	186	5
LA	116	47	1
SA	149	60	2
SD	98	40	1
SB	2072	838	22
SJ	2061	834	22
TL	3282	1328	35
NL	135	55	1
SL	83	33	1
CR	600	243	6
	9440	1820	100

1980 POPULATION



HSA	1,000,000 PEOPLE	% OF TOTAL
	0.4	1.9
	4.9	20.5
	1.0	[illegible]
	7.9	33.3
	3.0	12.6
	2.0	8.6
	1.6	6.9
	1.0	4.1
	1.2	5.0
	0.1	0.3
	0.3	1.3
	0.3	1.3
	23.7	100.0

Then, as the returns from the gold fields began to decline, some of the miners, as well as other newcomers to California, turned to farming. Water for irrigation took on increasing importance. In the northern and central parts of the State, irrigation practices were relatively simple. Individual settlers often dug ditches to convey water from streams to nearby fields. Artesian ground water was also plentiful in many valley and coastal plains in those years. In the southern part of California, however, somewhat drier conditions prevailed. Early irrigators learned to recognize the value of storage reservoirs, and several important dams had been completed or were under construction by the 1880s.

Until about 1900, water development in California was generally undertaken by individuals and private companies. Farmers formed groups to excavate irrigation ditches, and, during the 1870s and 1880s, development companies and cooperatives built irrigation works in San Joaquin Valley and Southern California. As the State grew and the need for water increased, private initiative was later supplemented by public endeavor. Community enterprises, irrigation districts, public utilities, and municipal projects of steadily increasing size and complexity arose. The Wright Irrigation District Act of 1887 and legislative changes to the Act in 1909 and 1911 gave strong impetus to the spread of irrigated agriculture. In authorizing the formation of local public irrigation districts, the original law declared the use of water for irrigation of district lands to be a public use and empowered districts to take over private irrigation enterprises and to acquire water. The earliest districts date from the 1880s. By 1930 more than 100 irrigation districts were in operation in California.

The cities of Los Angeles and San Francisco were early leaders in planning and developing projects to import water from other areas of the state. Later, regional organizations such as The Metropolitan Water District of Southern California and the East Bay Municipal Utility District developed large-scale import facilities.

Local plans for the use of water were conceived and executed without the benefit of a statewide framework to provide guidance and coordination. Although proposals for large regional water use schemes date from an 1874 federal investigation, the first statewide plan for development of California's water resources was set forth in 1920 by Colonel Robert B. Marshall, chief hydrographer for the U.S. Geological Survey. Marshall's proposal, which was privately published, was based on a comprehensive water plan for the entire Central Valley, by then a well-established agricultural region. Among other things, the Marshall plan called for a storage reservoir on the Sacramento River at the northern end of the Sacramento Valley and a pair of aqueducts, one to transport the stored water down the eastern side of the valley and one down the western side. The plan also included provision for conveying water to Los Angeles. Marshall's ambitious proposal captured much public attention, but its far-reaching concepts were viewed with disfavor by some government agencies and engineers.

Despite this, growing interest in the idea of a statewide plan for the orderly management of water, along with the interest aroused by the Marshall plan, led the Legislature in 1921 to direct the State Engineer to make a comprehensive statewide investigation of California's water resources. The study culminated in the publication of the *Report to the Legislature of 1931 on State Water Plan,* which outlined a coordinated plan for conserving, developing, and using the State's water. This was the first governmental proposal for transferring surplus water from Northern California to the southern part of the Central Valley. The plan was approved and adopted by the Legislature and designated as the State Water Plan.

Other reports that followed dealt in more detail with plans to develop water in the Sacramento and San Joaquin Valleys. Although many years were to pass before such broad plans were acted upon, these studies would ultimately form the basis for the Central Valley Project, built by the federal government, and the State Water Project.

The State filed water rights applications for potential dams and reservoirs in 1927. These reserved filings have been maintained in force by legislative acts, and supplemental applications have been made in subsequent years.

California Water Rights

The climate and the historical development of the State and its water resources have caused a complex body of water rights law to evolve. Competition among water users has emphasized the right to secure and use surface water. California does not now administer rights to ground water, except in instances where judicial decisions have required the implementation of intensive management.

California's surface water rights fall into two major categories: riparian and appropriative. Riparian rights go only with land adjacent to a watercourse or body of water. Holders of riparian rights have the right to use the natural flow of a stream, but they cannot store water.

In California most land is not situated adjacent to a body of water. The concept of the appropriative right was developed to allow for the water needs of such lands when other sources were not naturally available. An appropriative water right allows water users to transport water to any place of use, sometimes several hundred miles away, and to store water on either a short- or long-term basis.

Riparian rights come under the control of the courts only when there is a legal dispute among competing water users, or when an action has been filed against the users on the basis of waste or unreasonable use. Appropriators, on the other hand, secure a specified flow or quantity under their right. Before 1872, appropriators secured their water rights by merely taking and using the water. Between 1872 and 1914, a permissive procedure was provided that also allowed the initiation of a right by posting a notice at the point of diversion and filing a copy of the notice with the county recorder. These appropriative rights are limited both as to amount and season by the actual beneficial use of the water, notwithstanding the amount and season named in the original notice or as initially diverted.

After 1914, the State assumed administration of further appropriations of water and established a permit system that is now under the jurisdiction of the State Water Resources Control Board (SWRCB). Over the years, SWRCB has imposed numerous conditions in permits, based on public interest and prior right considerations. The key to the appropriative doctrine is the concept of priority: first in time, first in right. Riparian rights have equal priority and ordinarily are senior to all appropriative rights.

The filings for pre-1914 appropriative rights specify a rate or quantity of water, the point of diversion, the use to be made of the water, and the place of use. Permits for post-1914 appropriative rights specify the same four items. Any change in use, place of use, or point of diversion must comply with the prohibition against injury to other users. SWRCB has jurisdiction over all permit holders and must go through an administrative review process before permit conditions can be changed. Within these constraints, the user can divert the water and put it to any use, as long as the use is reasonable and not wasteful. When a permittee has completed appropriation within the time specified by SWRCB, a license is issued confirming the right to use the water.

Development of Ground Water Resources

The existence of ground water beneath much of California's land surface gave early-day farmers and ranchers the option of settling almost anywhere they wished. The widespread availability of enough underground water lying close to the surface meant that a family could supply itself and its livestock simply by digging a well or developing a spring. As pumping became practicable, it opened the way to even more water, ultimately leading to the State's flourishing agricultural industry. Ground water development in California has helped establish vigorous urban and agricultural economies that have been able to meet the costs of developing and importing surface water supplies, often from distant regions of

Water is pumped from the Sacramento River for use on adjacent land, in accordance with water right law.

the State Ground water today supplies 39 percent of the applied water used in California.

The water they drew from wells and springs for domestic use greatly benefited the health of early California settlers Before the days of water treatment facilities, polluted surface water was a major health problem. Where people took their water from streams and used them to carry off most of their wastes, the contaminated water transported disease organisms to other water users downstream. The use of ground water, which is often improved in quality by percolation through the soil and the granular media of aquifers, minimizes the transfer of water-borne diseases.

As California grew, wells were often the most economical means of obtaining good quality water for domestic and municipal uses in communities under-

Windmills were used widely in the early days, pumping ground water principally for domestic and livestock needs.

Few artesian wells exist today in California, but they were common in many locations 100 years ago.

lain by ground water basins. Ground water was frequently used in preference to surface water, even when a surface supply was available and could be treated and distributed. Ranchers found it more convenient to water their stock at the site with water obtained from springs and windmill-driven pumped wells.

Artesian wells were often used for irrigation in the early development of agriculture in California. These were an abundant source of water in the Central Valley and in many other valleys where underground pressure was sufficient to cause ground water to rise in wells to the surface and flow freely. Advances in well drilling techniques and equipment by the turn of the century enabled drillers to reach deep enough to penetrate these confined artesian aquifers.

In the early 1900s, development of the centrifugal pump, powered by gasoline engines or electric motors, allowed large quantities of water to be drawn from wells. Centrifugal pumps operating in pits 20 or more feet deep were fairly numerous through the early 1950s, and some remain in operation in California today.

Development of the deep well turbine pump and the wider distribution of electrical power to agricultural areas in the 1920s led to extensive use of ground water for irrigation, even where water had to be pumped from depths of several hundred feet. The application of ground water enabled farmers to irrigate large areas of land with relatively small capital outlay. Deep well turbine pumps also provided dependable supplies of municipal and industrial water for cities having good-sized populations, whose surface water sources dwindled in summer when streamflows declined or disappeared.

Today most ground water is extracted by deep well turbine pumps from depths of 100 feet or more.

Major Urban Water Development

The cities of San Francisco and Los Angeles were the prime movers in development and transport of water from distant sources for the use of urban residents. While the efforts of each city to increase its supply of water differed greatly in many respects, their goals were similar: to serve the future needs of the additional population each city expected to acquire. Both of these metropolitan areas grew rapidly throughout the latter half of the 1800s, and municipal leaders foresaw the time when the numbers of people would outstrip the available water.

San Francisco studied many possible sources of additional water for some 20 years and, by the turn of the century, finally settled upon the Tuolumne River, which flowed through the Hetch Hetchy Valley, part of Yosemite National Park in the Sierra Nevada. Hetch Hetchy was selected because it could store an ample supply of high-quality water and because the elevation was great enough to provide the drop needed to generate electrical power for San Francisco.

In the years preceding authorization of the project, the proposal to flood the Hetch Hetchy Valley aroused a great deal of controversy. It was vigorously opposed by John Muir, founder of the Sierra Club, and by many other conservationists. Competing water interests in the San Joaquin Valley also fought the city's plans on the grounds that they had prior rights to the water of the Tuolumne River. Because Hetch Hetchy Valley lay in federal reserved lands, the opinion of the Secretary of the Interior weighed heavily in the situation. For some years, the proposal was alternately accepted and rejected by successive Interior Secretaries, depending on the political position of each. Congressional legislation authorizing the Hetch Hetchy project was finally enacted in 1913.

Construction of the Hetch Hetchy Aqueduct began in 1914, and the first water to the city was delivered in 1934. The intervening years were marked by continuing disputes with a consortium of private utility companies over the question of the future sale of water and power from the project and by the need for repeated infusions of money to keep the work going. The Hetch Hetchy project cost $100 million, which was $30 million more than the builders originally calculated, but its benefits over the years have been substantial. San Francisco gains revenue from

the sale of more than half its water supply to other cities in the Bay area and also from the sale of power the project generates.

Faced with the same problem as San Francisco—an upswing in population—Los Angeles also undertook its first venture in long-distance water development early in this century. The Los Angeles Aqueduct, which carries enough water to meet about 80 percent of the city's needs, extends about 340 miles from the Owens Valley in Inyo County southward to Los Angeles. The project is also a power-producer, supplying a significant amount of electricity for Los Angeles.

Although not without its problems, construction of the Los Angeles project was initially relatively free of the kind of controversy that slowed the construction of the Hetch Hetchy development. First conceived about 1905, the Los Angeles Aqueduct was started in 1909 and completed four years later when Owens Valley water began arriving in Los Angeles. This was a situation in which local irrigation water was purchased (land and associated water rights) and transported from the drainage basin for urban use.

The 1920s were marked by strong local opposition to the project. Owens Valley ranchers, angered by the acquisition of the valley's land and water and the city's action to prevent certain upstream diversions, blew up the aqueduct in 1924 and again in 1927, at which time Los Angeles sent armed guards to protect the project. The valley's violent resistance ended shortly afterward, although the controversy has continued to the present. In 1940, the system was extended farther north to Mono Lake, and, in 1970, a second aqueduct from Owens Valley was built along a similar route.

Only a few years after the completion of the first Los Angeles Aqueduct, the city was considering other means of expanding its sources of water and power. In 1920, Los Angeles went on record as favoring the construction of engineering works (as a federal project) to regulate the erratic flows of the Colorado River and thus make the river a reliable resource for all users. Approval of the federal Boulder Canyon Project Act in 1928 paved the way for development of the Colorado River, including construction by the federal government of Boulder Dam (later Hoover Dam), completed in 1936. Regulation of the river ensured a dependable supply of water for the Los Angeles area. Construction of the Colorado River Aqueduct was undertaken by a consortium of Southern California communities, joined as The Metropolitan Water District of Southern California. The 240-mile-long facility was completed in 1940, and deliveries commenced the following year.

Major Agricultural Water Development

Before World War II, irrigated agriculture in California relied largely on development by irrigation districts of local surface water supplies and pumping of ground water. The area under irrigation reached 4 million acres by 1930, concentrated chiefly in the Central and Imperial Valleys, and the South Coast area. The need for supplemental sources of water to halt falling ground water tables in the San Joaquin Valley portion of the Central Valley gave impetus to a comprehensive program of water importation.

Water transported by the Los Angeles Aqueduct moves through an inverted siphon across Jawbone Canyon, about 100 miles from the terminus of the system.

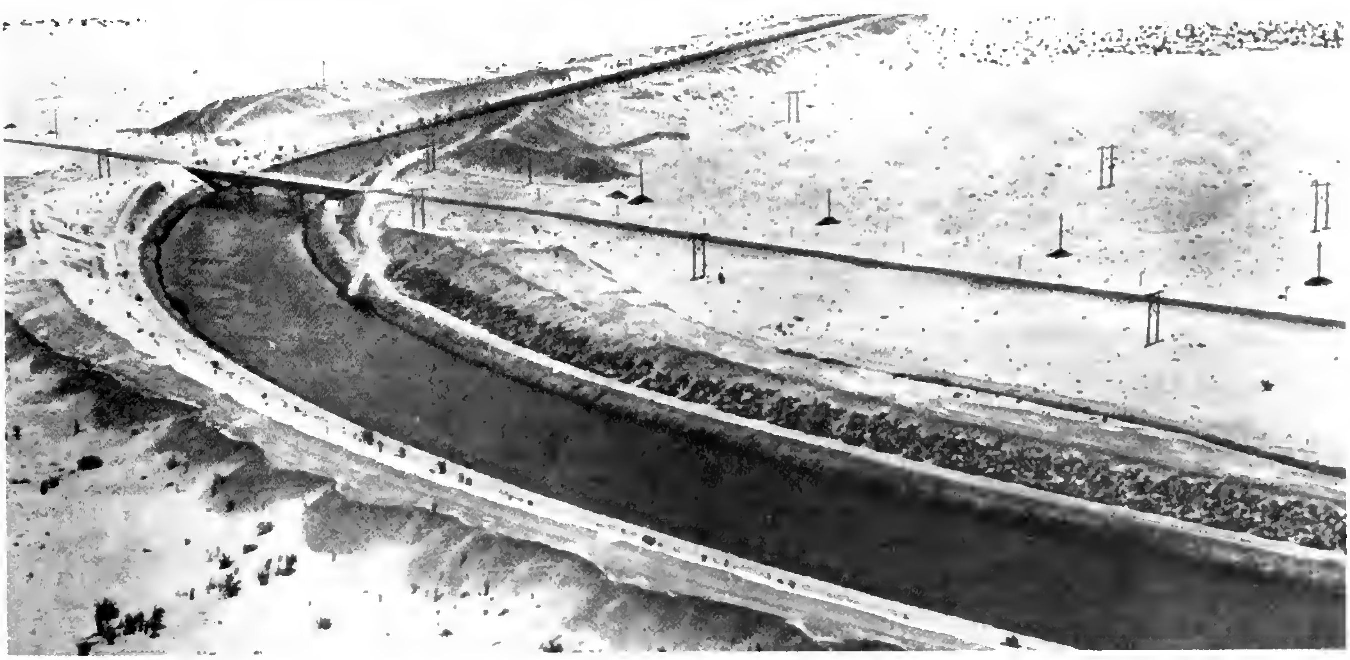
The federal Reclamation Law of 1902 made possible the use of federal funds for large-scale, inexpensive development of irrigation for agriculture in the western states. One of the first projects built under the 1902 Reclamation Act and the first such built in California, was the Orland Project, located on the west side of the Sacramento Valley west of Chico and Orland. Construction of the project began in 1903 and was completed by 1928. The project consists of East Park and Stony Gorge Dams, several smaller diversion dams, and a distribution and drainage system. In 1954 the U. S. Bureau of Reclamation transferred operation of project facilities to the Orland Unit Water Users Association.

The Imperial Valley is located in southeastern California near the border common to California and Arizona and the international boundary with Mexico. Development of irrigated agriculture was begun by the California Development Company, which was formed in 1896 to irrigate the valley with water from the Colorado River. The company constructed an unlined canal from the Colorado River to the Imperial Valley. In 1905, the bank of the Colorado River gave way and the river flowed into the Salton Sink for almost two years, creating the present-day Salton Sea. Flood-related costs caused the company to go into receivership, and in 1916 its Colorado River water rights were acquired by the newly formed Imperial Irrigation District. The district initially sold and distributed water but later took a more active role in water and power development. The Boulder Canyon Project Act of 1928, which authorized construction of Hoover Dam, also authorized construction of the All-American Canal by the federal government, and, with the initial delivery of water through the All-American Canal in 1940, the Imperial Valley became a major agricultural region in California

In 1933, California voters approved a $170-million bond measure to finance the start of work proposed in the 1931 State Water Plan, but the State's plans were thwarted when the market for bonds evaporated in the nationwide depression in the 1930s. As a result, the major work of water development in Northern California at that time fell to the federal government. The Central Valley Project, constructed by the U. S. Bureau of Reclamation, extends from near Mt. Shasta on the north to the southern end of the San Joaquin Valley. The multipurpose project's numerous dams, reservoirs, and canals, which were intended principally to develop water for irrigation, also help control floods; generate electric energy; improve river navigation; supply domestic and industrial water; protect water quality, and fish and wildlife habitat; and provide settings for recreation. Construction of the first unit of the CVP began in 1937; work on additional units continues today.

The California Water Plan

Immediately after World War II, attention at the State level turned to updating planning studies done in the late 1920s and early 1930s. In 1947, at the direction of the State Legislature, the Division of Water Resources (predecessor of the Department of Water Resources) began the Statewide Water Resources Investigation. This investigation consisted of three phases:



After leaving the Colorado River, the All-American Canal crosses an expanse of desert to reach the Imperial Valley.

- Identification of the water resources of California,[1]
- Determination of present and potential "ultimate" water requirements, and
- Planning for the orderly development of the State's water resources to meet its potential ultimate requirements.

The first phase of the investigation was a statewide inventory of sources, quantities, and characteristics of water in California. The results were presented in 1951 in *Water Resources of California*, Bulletin 1,[2] a concise compilation of data on precipitation, runoff, flood frequencies, and water quality throughout the State.

Estimates of present and ultimate water requirements, published in 1955 in *Water Utilization and Requirements of California*, Bulletin 2,[2] made up the second phase of the study. The report presented the statewide water use in 1950 for all consumptive purposes and forecast ultimate water requirements.

The final phase of the investigation involved a statewide plan, published in 1957 in *The California Water Plan*, Bulletin 3.[2] This report described a comprehensive master plan to guide and coordinate the planning and construction of facilities required to control, conserve, protect, and distribute the water of California to meet present and future beneficial needs throughout the State.

The plan identified watersheds where current surplus supplies existed and areas where deficiencies were forecast, identified existing and potential water problems, and suggested methods for distributing the State's water for beneficial use in all areas. Designated as the initial unit of the plan was the State Water Project (then called the Feather River Project), which was recommended for immediate construction. The plan also recognized watershed management, sea-water conversion, waste water reclamation, and weather modification as possible means of supplementing California's water supply. The plan demonstrated that available water, including rights to Colorado River water, was adequate for full development of agricultural and urban areas of the State, and that physical accomplishment of these objectives was possible within prevailing water management policies. The total net water requirement in 1950 was about 21 million acre-feet and was forecast to increase ultimately[3] to over 51 million acre-feet.

[1] The concept of the California Water Plan as an "ultimate" plan is based generally on the developmental capability of the land. As explained in Bulletin 3, the concept "pertains to conditions after an unspecified but long period of years in the future when land use and water supply development are at maximum and essentially stabilized."

[2] Bulletins 1 and 2 cited here were published by the (then) State Water Resources Board. Bulletin 3 was published by the Department of Water Resources.

The California Water Plan was intended to provide a flexible framework into which future specific projects could be integrated. It was also understood that the plan would be modified and improved as more detailed information became available and as changes were dictated by shifts in public policy and other unforeseeable events. Bulletin 3 concluded the Statewide Water Resources Investigation. However, intensive studies by the Department of Water Resources were continued to (1) identify plans and programs to meet local and statewide water needs, (2) analyze their economic justification and financial feasibility, and (3) determine their priority of implementation. This work continues today. Subsequent periodic updates are discussed later in this chapter.

The projections presented in Bulletin 3 were based on California's rapid expansion in population, industry, and agriculture during and immediately following World War II. In 1940, California had a population of about 7 million; by 1950 the population was about 10.5 million, and, by 1955, it had increased to more than 13 million. This growth, and similar growth in industry and agriculture, dramatically increased the need for water.

Update of the California Water Plan

The 1957 California Water Plan was the first comprehensive master plan for statewide water development. Since 1950, the base year for the study, urban and agricultural use has been changing continuously as population has grown and agriculture has expanded. Moreover, public values regarding water have changed substantially over recent years, and the plan has needed periodic revision to accommodate all these changes.

Statewide planning studies to update the California Water Plan have continued since 1961. The studies have incorporated economic considerations into projections of future water needs (as contrasted to "ultimate requirements" in Bulletin 2) and have analyzed the staging of additional water supply developments, together with other water management options, to meet the projected water needs. Results of the studies have been presented in the Bulletin 160 series of reports. The present report is the fourth major update of the plan. The three previous reports and the significance of changes to which they responded are discussed in the following sections.

The 1966 Update

In 1966, the Department of Water Resources published *Implementation of the California Water Plan*,

[3] Ultimate requirements were based on full development of all land defined as irrigable, 16.2 million acres, and an estimated urban acreage of 3.6 million acres.

Bulletin 160-66, the first of the 160 series of bulletins. That report assessed the changes that had occurred in the years since the California Water Plan was first published. The base year for the 1966 report was 1960.

The State's population had grown from about 10.5 million in 1950 to about 16 million in 1960, an increase of almost 45 percent. California was fast becoming the most populous state in the nation. Based on this rate ofgrowth, Bulletin 160-66 projected that there would be more than 35 million people by 1990, and 54 million by 2020 (Figure 2). Total net water use in 1960 was about 23 million acre-feet. This was projected to increase to over 31 million acre-feet in 1990 and about 38 million acre-feet in 2020 (Figure 3).

California's growth rate was matched by a stepped up pace in water development. In 1960, California voters approved financing of the State Water Project, a major project identified in the California Water Plan as a means of transferring surplus water to areas of need. By 1966, California was in the midst of an accelerated water development era. Much of the State Water Project was under construction, and the U. S. Bureau of Reclamation (USBR), the U. S. Army Corps of Engineers (USCE), and local agencies were intensifying their water resource planning and construction activities.

Projections made in Bulletin 160-66 indicated much higher population growth than later occurred; however, the continued growth in irrigated agriculture that took place between 1966 and 1982 was *not* anticipated at that time (Figure 4). Concern was noted regarding flood control needs, but the report recognized that nonstructural approaches, such as flood plain management, must occur. Increasing growth of power demands and some of its implications were discussed. Needs for water-related recreation, the relationship of fish and wildlife to water development, and water quality control were also discussed as water management policy concerns.

The 1970 Update

The California Water Plan was updated a second time with publication in 1970 of *Water for California: The California Water Plan: Outlook in 1970*, Bulletin 160-70. The base year for that report was 1967.

By 1967, three million more people were living in California than in 1960, bringing the total to 19 million. This increase represented an average annual growth of about 430,000, a drop from the average annual growth of 500,000 from 1950 to 1960. The slowdown was caused by reductions in both births and immigration. This trend was used to revise population projections to 29 million for 1990 and 45 million for 2020, with a corresponding reduction in estimated future urban water use (Figure 2). Estimates of irrigated acreage were also reduced (Figure 4), but, with the availability of more accurate information on the consumptive use of crops and the extent of water reuse, estimates showed a likely overall increase in net water use. Net water use was projected to be more than 34 million acre-feet for 1990 and about 40 million acre-feet for 2020 (Figure 3). With the projects then under construction or authorized, the report concluded that sufficient water supplies would be available to meet most of the 1990 requirements.

The 1970 report also expressed concern about flood control, water-related recreation, and water requirements for energy production, and, for the first time, noted the need for ". . . more attention to the emerging environmental problems associated with water conservation projects and the evolvement of definite public policies on such problems." Specific environmental issues identified in the report included the need to classify California's rivers, protect and enhance fisheries and wildlife habitat, and maintain acceptable water quality. In addition, the relationship of water and land development was recognized in a major section of the report devoted to a discussion of alternative land use policies and population dispersal. The report concluded that, although total statewide water demands would be unchanged, new population centers would require altered patterns of water transportation facilities.

Probably the most significant conclusion stated in Bulletin 160-70 was that the projected slower population growth, together with additional water supplies being developed or authorized, would provide a breathing spell that would allow more time ". . . to consider alternative sources of water supply and develop policies for the maximum protection of the environment." The report specifically recognized the need for a comprehensive policy framework that would provide a clearer view of water resource development, but concluded that: "Until such policy is articulated by the State, the Department must continue its philosophy and policy of ensuring that the water needs of the people are satisfied. . . ." The trend toward increasing environmental awareness was noted for both the national and State levels, in addition to legislative action in response to this new direction.

The 1974 Update

When the third update, *The California Water Plan: Outlook in 1974*, Bulletin 160-74, was published in 1974, it reported that, by 1972 (the base year for that report), the population had reached about 21 million, indicating a continuing slowdown in the rate of growth. Population projections were again revised downward to about 27 million for 1990 and about 37 million for 2020. While projected urban water use was lower than earlier estimates, projected irrigated agricultural acreage and water use were greater. The net result was that the total projected net water use

Figure 2. COMPARISON OF CALIFORNIA POPULATION PROJECTIONS
BULLETIN 160 SERIES

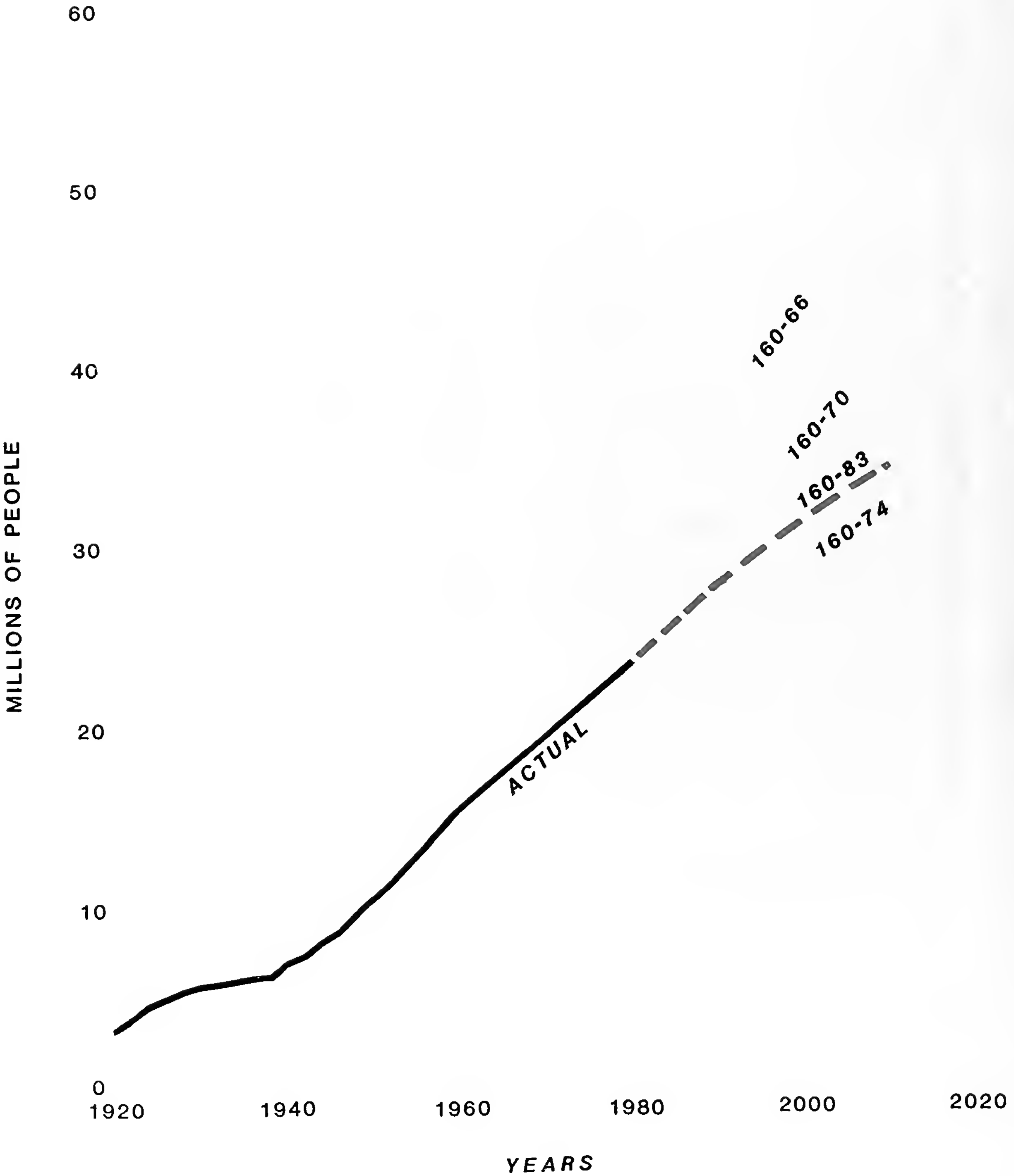


Figure 3. COMPARISON OF TOTAL NET WATER USE PROJECTIONS

BULLETIN 160 SERIES

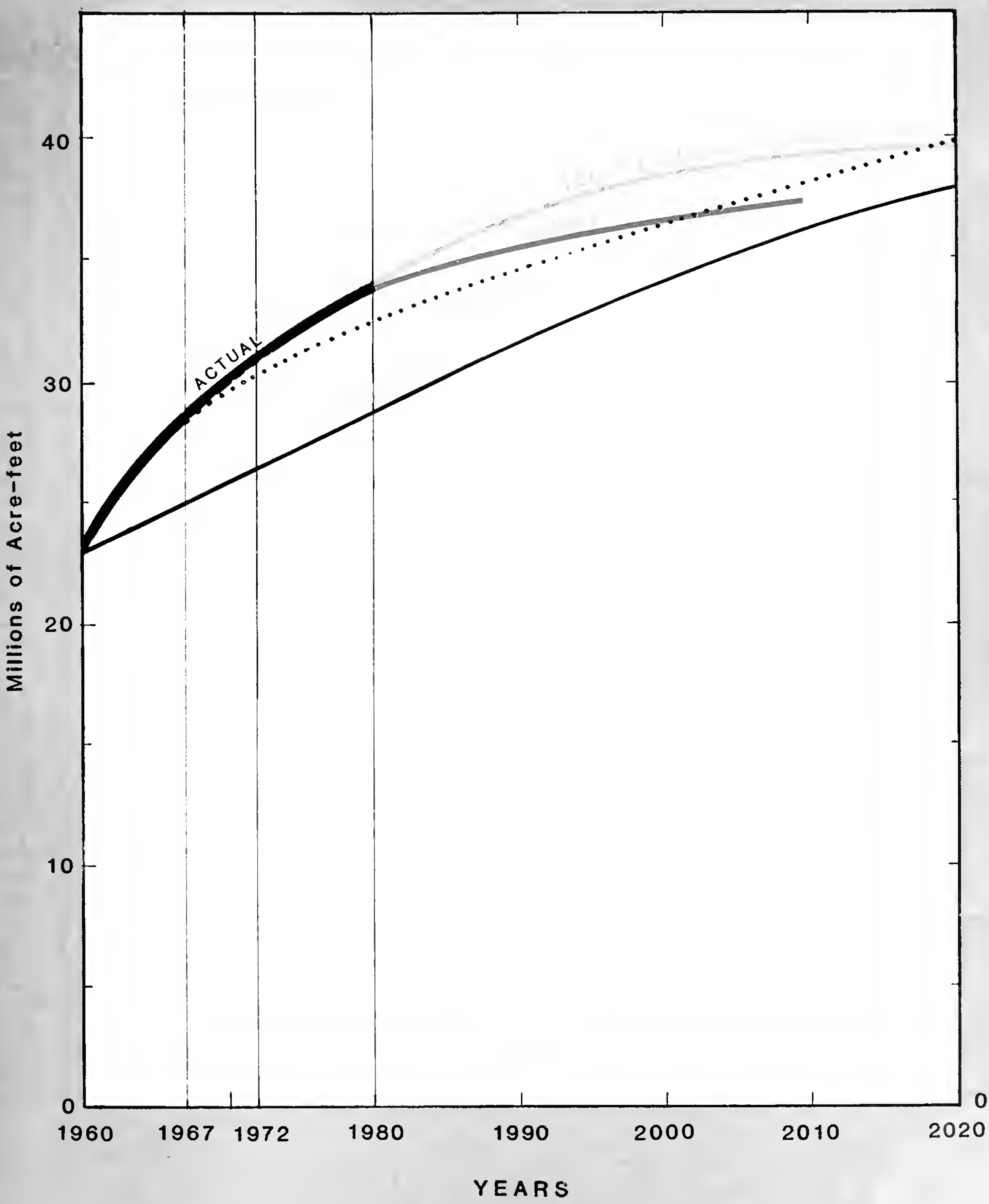
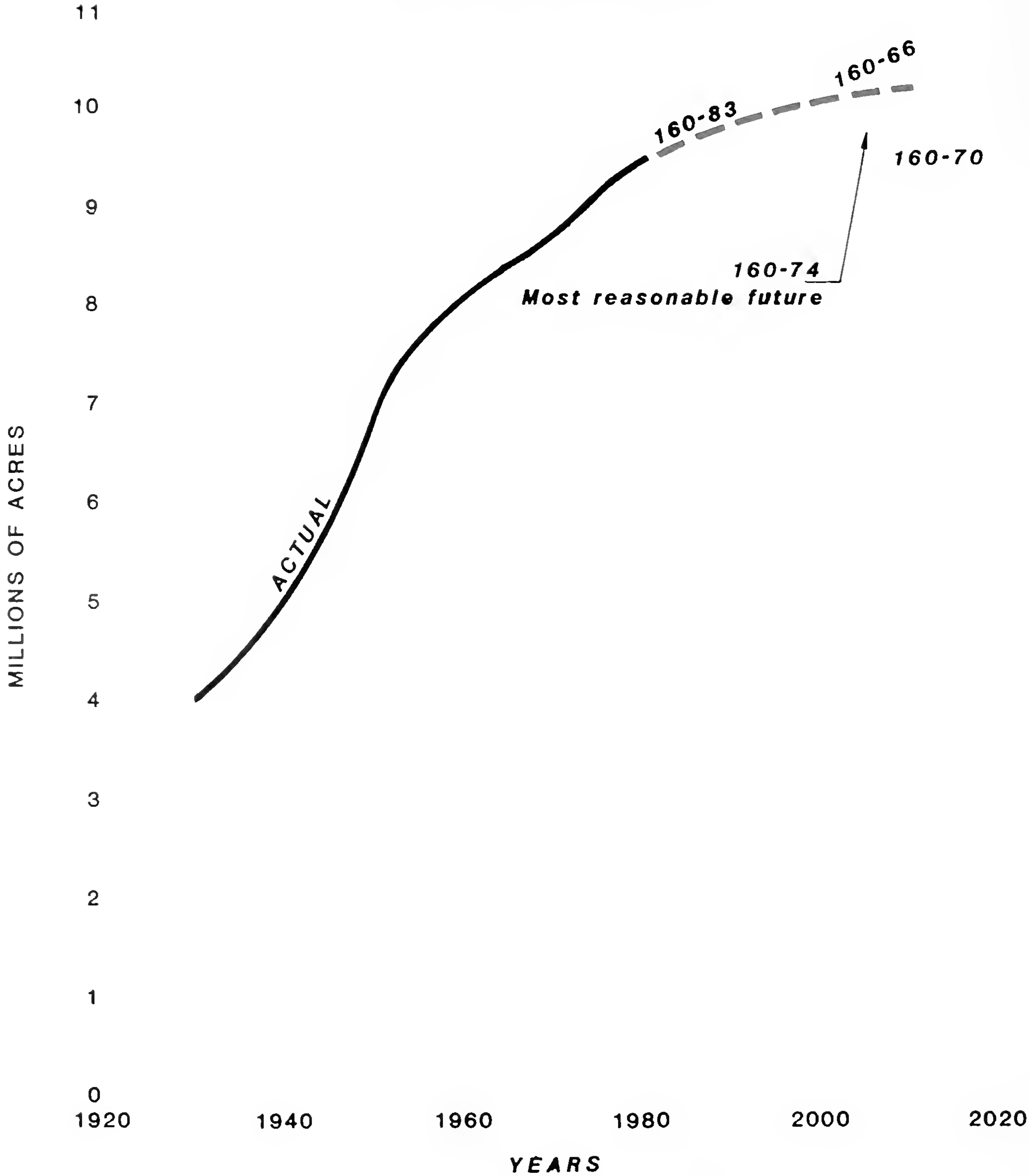


Figure 4. COMPARISON OF IRRIGATED LAND PROJECTIONS
BULLETIN 160 SERIES



for 1990 rose to about 37 million acre-feet, and projected net use for 2020 remained about 40 million acre-feet, the same amount shown in Bulletin 160-70 (Figure 3).

Bulletin 160-74 concluded that the status of available supplies, compared to the (then) present use, was favorable. This conclusion was based on the premise that the Auburn, New Melones, and Warm Springs Reservoirs and the Peripheral Canal would be operational by 1980. The report was less conclusive about the extent to which supplies would satisfy future water needs, considering the increase in requirements for stream water quality and the setting aside by the California Legislature of wild and scenic rivers, primarily in the North Coast area of California. (Both factors are discussed later in this report.)

The bulletin includes a chapter devoted to a discussion of key water policy issues, including cooling water for electric energy production, water deficiencies (risk), water exchanges, public interest in agricultural drainage (San Joaquin Drain), water use efficiency (water conservation), economic efficiency (water transfers), and waste water reclamation. (Some of the still-relevant issues are considered in Chapter VI of this report, Bulletin 160-83.)

Water Quality Control Planning

Water quality control is the responsibility of the State Water Resources Control Board (SWRCB). California's Clean Water Bond Act of 1970 provided funds to develop a water quality control plan, or Basin Plan, for each of the 16 water quality planning basins in the State. With the adoption of the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500), each state was also required to submit to the Environmental Protection Agency (EPA) similar water quality control plans. Basin Plans covering all 16 California basins were prepared by SWRCB staff, adopted by the various California Regional Water Quality Control Boards, approved by SWRCB in 1975, and approved (some conditionally) by EPA soon thereafter.

From the perspective of impacts to California's water supplies, perhaps the most important of the basin plans is that for the Sacramento-San Joaquin Delta. The 1975 Basin Plan provided for protection of the Delta's varied beneficial uses of water through a set of water quality objectives, which were similar to requirements in Decision 1379 of SWRCB, a decision pertaining to water rights for the State Water Project and the federal Central Valley Project.

In August 1978, SWRCB adopted the Water Quality Control Plan for the Sacramento-San Joaquin Delta and the Suisun Marsh (the Delta Plan) and the corresponding water rights Decision 1485, which superseded Decision 1379. Both documents amend water quality standards related to salinity control and protection of fish and wildlife in the San Francisco Bay-Delta estuary. Standards are based generally on the degree of protection that municipal, industrial, agricultural, and fish and wildlife uses would otherwise have experienced, had the State Water Project (SWP) and Central Valley Project (CVP) not been built. The new standards require that the SWP and CVP make operational decisions to maintain Delta salinity and to meet Delta fresh-water outflow within specified limits. These revised standards are in addition to nonsalinity standards in the 1975 Basin Plan, which remain in effect.

Federal law (Public Law 92-500) requires that all water quality basin plans receive a triennial review. Since 1975, SWRCB and the nine regional water quality control boards have made numerous amendments to the plans as needed. Such periodic updating occurs outside the formal triennial review.

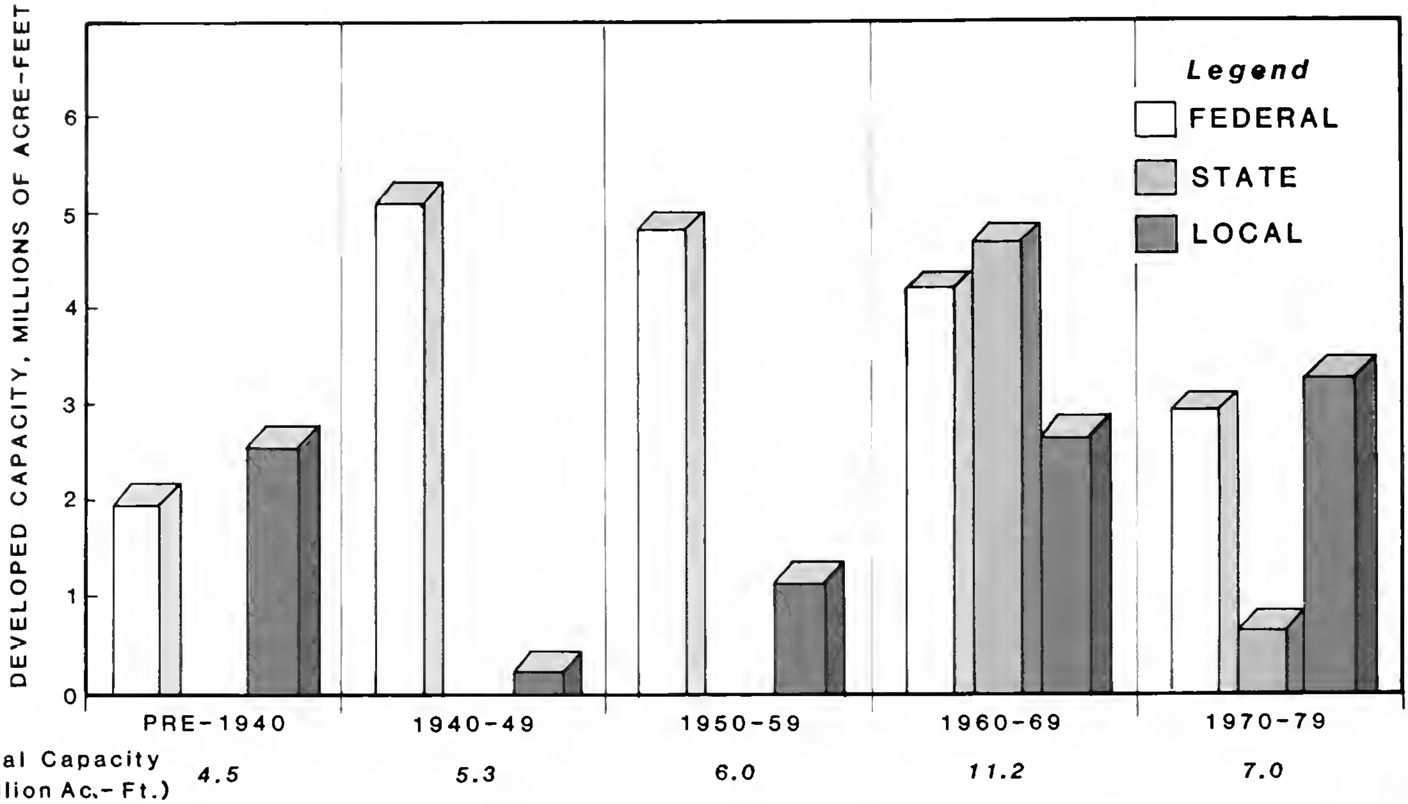
The status of water quality problem areas is discussed at length in other publications, especially in SWRCB's most recent biennial report, *Water Quality/Water Rights, 1978–80 Report.*

Recent Water Supply Developments

Although several significant projects were built before 1950, most of California's present reservoir capacity has been developed since the early 1950s. The historical development of reservoir capacity in California, by decade, is shown in Figure 5.

Tullach Reservoir in Calaveras County, a local facility built in the 1950s.

Figure 5. HISTORICAL DEVELOPMENT OF RESERVOIR CAPACITY IN CALIFORNIA
(Reservoirs of more than 75,000 acre-feet)



Development during the 1950s was a mix of federal and local projects, including Donnells, Beardsley, and Tulloch Reservoirs on the Stanislaus River; Cherry Valley Reservoir on Cherry Creek; Lake Piru on Piru Creek; and Nacimiento Reservoir on the Nacimiento River—all local projects; and Casitas Lake on Coyote Creek, Folsom Reservoir on the American River, Lake Isabella on the Kern River, and Lake Berryessa on Putah Creek—all federal projects.

The decade of the 1960s was an era of State Water Project development, and Lake Oroville on the Feather River was completed by the Department of Water Resources in 1968. Other projects completed in the 1960s include Camanche Reservoir on the Mokelumne River, the Upper American River Project, New Exchequer Reservoir on the Merced River, and San Antonio Reservoir on the San Antonio River—all local projects; New Hogan Reservoir on the Calaveras River, Clair Engle Lake (Trinity Dam) and associated transport facilities on the Trinity River, and Terminus Reservoir on the Kaweah River—all federal projects; and the offstream San Luis Reservoir on the western side of the San Joaquin Valley near Los Banos, a joint State-federal project. About one-third of California's current reservoir capacity was added during this decade. (A list of major reservoirs appears in Chapter III.)

With the 1970s came a slowdown in development, although significant new capacity was added by local public districts and the State and federal governments. Major projects completed through 1979 include New Bullards Bar Reservoir on the Yuba River, the Indian Valley Project on Cache Creek, and New Don Pedro Reservoir on the Tuolumne River—all local projects; Buchanan Reservoir on the Chowchilla River, Hidden Reservoir on the Fresno River, New Melones Reservoir on the Stanislaus River, and Stampede Reservoir on Little Truckee River—all federal projects; and four State Water Project terminal reservoirs in Southern California: Pyramid, Castaic, Silverwood, and Perris.

Foundation and other preparatory work for construction of Auburn Dam, a CVP feature authorized by Congress in 1965, was halted by the concerns for safety raised by the Oroville earthquake of 1975. This event led to a major seismic safety study, as a result of which the dam's design was changed in 1980 from a concrete arch to a concrete gravity structure. Because construction cost estimates now exceed the

original authorization, full reauthorization is necessary before work on the dam can be resumed.

Not all the reservoir capacity identified in Figure 5 translates into water supply yield. Large amounts of storage reserved for flood control produce little or no yield, and storage projects operated primarily for hydroelectric power generation develop less yield unless downstream re-regulatory storage is available. Variations in stream hydrology also affect yield. A few major reservoirs were developed for long-term carryover storage (water stored for use over several dry years), which means that storage capacity is several times the firm annual yield. Examples of such facilities are Shasta, Oroville, Berryessa, and New Melones. Most of the post-1950 yield is associated with new reservoirs. During the 1960s and 1970s, some development occurred at those sites that were already developed, and several "new" dams were built that inundated older reservoirs (for example, New Melones, New Bullards Bar, and New Don Pedro).

Almost one-third of California's developed surface water supplies is associated with the federal Central Valley Project and the State Water Project. Both projects have spanned decades of development and serve water over a wide geographic area. The CVP serves primarily agricultural uses in the Central Valley, while the SWP delivers water to agricultural, municipal, and industrial users in the San Francisco Bay area, the Central Valley, and Southern California.[4] Construction of the CVP began in the 1930s, and its builder, the U.S. Bureau of Reclamation, continues to plan for additional elements of the project. The SWP, authorized by the electorate in 1960 and built by the Department of Water Resources, has been under construction since the early 1960s. The CVP has developed under a program that determines water supply needs, constructs facilities, and subsequently negotiates water supply contracts. The SWP has been developed quite differently. The Department contracted for the planned maximum yield of SWP facilities before the facilities were constructed. Water service contracts provide for delivering increasing amounts of water to contractors over time, with staged construction of facilities to make additional water available on a schedule in accordance with the increasing contractual demand.

Ground water has continued to supply a major portion of the total water applied. In 1955, ground water supplied an estimated 12 million acre-feet of the 28.9 million acre-feet used. In 1965, ground water was estimated to furnish about 16 million acre-feet of the 33.6 million acre-feet used. By 1972, this level of use had dropped slightly to 15 million acre-feet, and it has remained about the same since then.

[4] More detailed information on the history and features of the CVP and the SWP is shown in Chapter III.

When the land overlying a ground water basin is fully urbanized or fully devoted to irrigated agriculture, the water needs of such an area usually exceed the amount of water that replenishes the basin. If this situation continues for some years, the basin is described as being in a state of overdraft. The water table falls, pumping costs increase, wells must be deepened, and poor quality water sometimes enters the wells. These effects, along with the wish for a dependable water supply, often prompt water users to seek a supplemental supply.

Continuing heavy reliance on ground water in California has caused severe overdraft to occur in portions of basins in Southern California, along the Central Coast area, and in the San Joaquin Valley. Most of the overdraft in Southern California has been overcome during the last half-century by importing additional water and by adjudicating or by management of the ground water basins by local water agencies. Imported water supplies have lessened but not eliminated ground water overdraft in the San Joaquin Valley. The effect of the imports has been offset by the continuing growth of irrigated agriculture. Ground water overdraft has continued to increase in the Central Coast area. Overdrafts in the coastal portions of the area have, in some cases, caused sea water to intrude into coastal basins.

The Drought of 1976 and 1977

Although California has experienced other periods in which precipitation was unusually light, the drought years, 1976 and 1977, proved to be the driest two-year period in the State in 125 years of weather record-keeping.[5] Considered individually, 1976 was the fourth driest water year of record, and 1977 was the driest.

While drought losses for the two years totaled more than $2.5 billion, for the most part the State came through the period remarkably well, largely because of the way in which both individuals and water service agencies adjusted to often-difficult conditions. Once convinced of the seriousness of the situation, the public responded whole-heartedly. Likewise, water agencies worked together, where possible, to pool their supplies.

For many water agencies, the drought was a valuable learning experience. For example, after the quantities of runoff in 1976 were known, some immediate questions were raised. How dry is 1977 going to be? What about 1978? How much risk should be taken? The answers were not readily forthcoming. The art and science of long-range weather forecasting were not (and are not now) sufficiently developed to be relied upon. Many farmers wanted full water deliver-

[5] In California, hydrologic data are recorded by 12-month water years that begin on October 1. However, for ease of expression, in this report the recent drought years are identified as 1976 (for 1975–76) and 1977 (for 1976–77).

es in 1976 and were willing to take the chance that 1977 rainfall would be nearly normal. For urban water purveyors, rationing plans had to be devised and put into action. In metered areas, revenues from water sales declined, while operating costs remained essentially the same, creating financial problems for water agencies. When water rates were raised, users complained about paying more for less water. Overall, however, the public responded very positively to requests to conserve water and, in fact, as the drought worsened, even exceeded conservation goals in many instances.

Effects of the Drought

Probably those hardest hit economically were the businesses that depend primarily on precipitation to continue operating—ranches and recreation facilities, particularly ski resorts. Cattle ranchers sold their herds sooner than planned or bought expensive feed to make up for the lack of grass for grazing. Some ski resorts did not reopen in 1977 after a very poor 1976 snowfall season. Reservoir recreation areas were also severely affected, with many facilities made unusable by greatly lowered reservoir levels. Recreation in the national forests and state parks was curtailed by water shortages in campgrounds and extreme fire hazard conditions. The forests suffered heavy indirect losses from increased insect damage and disease occasioned by stress from lack of moisture.

Many cities and communities had to resort to such emergency measures as temporary importation of water from other regions of the State, drilling of new wells, mandatory conservation and, in the most severely limited areas, rationing to meet basic essential water needs. Lowered reservoir levels and reduced streamflows cut greatly into hydroelectric energy production. In 1977, statewide hydroelectric generation was only 33 percent of normal output. The deficit in Northern and Central California was made up at much higher cost by additional fossil-fueled generation and purchases from Southern California utilities.

Lessening of the Drought's Effects

Major federal legislation was passed in 1977 that provided funds to assist California's drought victims, making loans and grants available to augment, use and conserve water for irrigation; to improve community water systems; to purchase and transport water; and to promote water conservation.

At the end of the second drought year, most surface reservoirs had fallen to or below normal minimum operating levels. Fortunately, Lake Mead and Lake Powell on the Colorado River were nearly full, which permitted The Metropolitan Water District of Southern California (MWD) to use surplus Colorado River flows in place of State Water Project water. MWD agreed to reduce its demands on the project by up to 400,000 acre-feet, thereby making water available to agricultural users in the San Joaquin Valley and to urban users in the San Francisco Bay area. One such specially arranged transfer was designed to relieve water-short Marin County, where supply additions had been rejected in an attempt to control growth. This transfer involved pumping an emergency supply from the Sacramento-San Joaquin Delta by way of the facilities of the State Water Project, the city of Hayward, the San Francisco Water Department, and the East Bay Municipal Utility District, and, finally, through a temporary pipeline laid on the deck of the Richmond-San Rafael Bridge.

Perhaps the most significant factor in minimizing losses during this period was the immense ground water reservoir that underlies the Central Valley of California. Overall, water users who had access to ground water felt the drought's effects the least. Although some farmland that was customarily irrigated had to lie fallow, total reductions of producing acreages were held to a minimum because this vast underground resource was available. Some farmers were able to shift to crops that use less water and practiced less double-cropping than usual. These actions saved water, but they also tended to reduce farm income. Agricultural production costs increased because farmers were using ground water in place of cheaper but generally unavailable surface water. It was costly for them to drill or deepen thousands of wells and pump water from increasing depths. In the two drought years, ground water pumping was increased by 3.3 million acre-feet in the San Joaquin Valley alone and, in the State as a whole, by 4.5 million acre-feet.

The Drought's Outcome

In retrospect, the 1976–1977 drought reinforced views of certain aspects of water management and provided a new perspective on others. Certainly, it demonstrated the importance of preserving ground water as a viable source of water and operating it as a long-term supply—to be used but not to be so depleted that it cannot serve as an economic resource. The drought also demonstrated that urban users were able to reduce water use more readily and with fewer adverse effects than could agricultural users. This fact suggests that the present policy of requiring agriculture to take the first and largest deficiencies should probably be re-evaluated. The drought also forced implementation, to some degree, of several options that are discussed in Chapter VI of this report, primarily water transfers and changes in water project operating criteria.

Further information on the drought and its effects are presented in the Department's May 1978 report, *The 1976–1977 California Drought—A Review*, and in preceding reports issued during 1976 and 1977. For implications of future dry periods or droughts, see especially the concluding section, "The Lessons Learned," in the May 1978 report.

Need for and Significance of Water Use Projections

The basic purpose of projecting a level of future conditions is to facilitate informed decisions about that future by those affected by it. The projections in this series of reports, like most projections, were, and are, not intended to be accurate portrayals of future reality nor self-fulfilling prophecies. Rather, they are attempts to present the potential future consequences implied by the choices that Californians made or were making at those points in time. They also forewarn of the need to make decisions, if trends continue, or to modify past decisions, if trends change direction.

Past projections of land and water use, made in the Bulletin 160 reports, have demonstrated the effect of extrapolating past and current trends into the future. They have included population and the factors influencing the growth of population and irrigated agriculture. The projections have been intended to provide reasonable lead time for decisions and actions necessary to implement the most effective means of satisfying water needs. At the same time, they provide a basis to:

- Evaluate the factors that make up the trends.
- Determine the long-range effect of current land use and water management decisions.
- Judge whether current water management policies will fulfill their purpose.
- Develop and promulgate new policies and programs.

Trends vary in directions, however, and events that cannot be foreseen today subject such projections, correspondingly, to increasing change with the passage of time. Accordingly, the estimates of the future presented in this report represent only the magnitudes or conditions foreseen *at the present time*. Periodic revision in light of additional information and experience will continue to be necessary, and revisions may be either upward or downward.

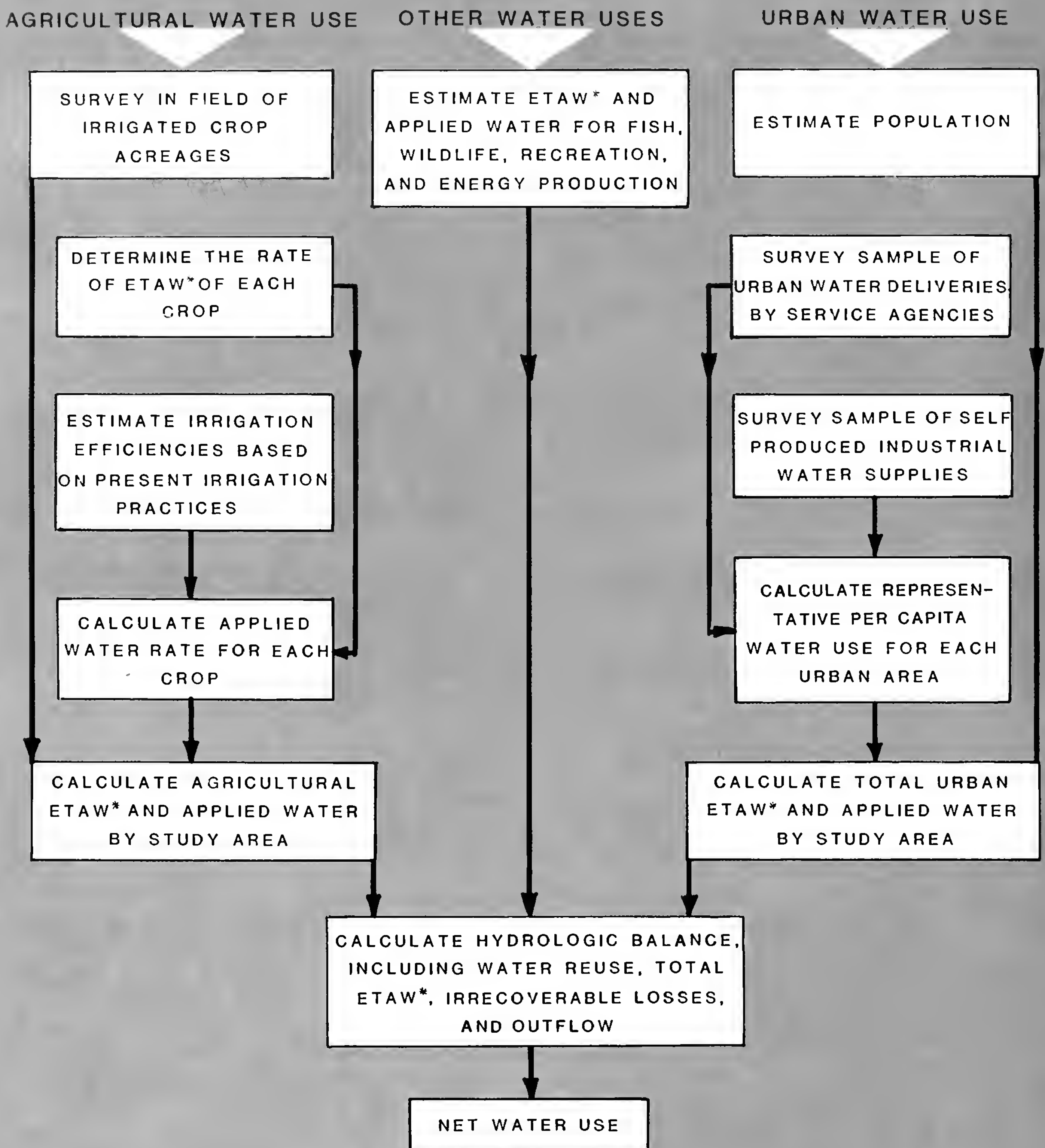
Some perspective may be gained by reviewing briefly the Department's experiences in making projections in the Bulletin 160 series. For example, Bulletin 160-66 based population projections on the high growth rate experienced during the preceding 20 years. However, population growth rates declined during the late 1960s, which caused the Department to adjust its forecasts downward in Bulletin 160-70. A further drop in growth during the early 1970s resulted in a further flattening of the future trend line in Bulletin 160-74. The most recent population trends have resulted in a future trend line slightly higher than in Bulletin 160-74, but lower than that in Bulletin 160-70. These projections are shown in Figure 3.

Historic and projected net water requirements for all consumptive purposes shown in Figure 4 reveal that the Department's projections have tended to be conservative. The relatively large increase from Bulletin 160-66 to Bulletin 160-70 does, however, reflect the inclusion of more accurate information on consumptive water use of crops and the extent of reuse that resulted in projecting greater net water use.

Projections of irrigated land have demonstrated similar variability. Figure 5 shows projections of irrigated land for updates of the California Water Plan published in 1966, 1970, and 1974. The Department has tended to underestimate the rate of such development. Several factors may be responsible for this, including a lack of complete understanding (even in academic circles) of the full complexity and flexibility of the agricultural system in California. Time and again, the industry has demonstrated its ability, both collectively and on the part of the individual farm operator, to react in a positive way to continually changing market and economic conditions. This ability is probably due in part to the favorable climate that gives the farmer a wide choice of crops to raise and, at least until recent times, in part to the ready availability of relatively low-cost water.

The comparisons in this section have been prepared to point up the significance of the differences that have occurred between what we thought *might* happen, had trends continued, and what actually did happen or what we now think might happen. The future which Californians will eventually inhabit will be largely, though not completely, a matter of choices made in the present. The projections and other information on water use presented later in this report have been prepared in the hope that they will stimulate critical review and discussion by Californians of those choices.

Figure 6. STEPS IN DETERMINING PRESENT WATER USE



* EVAPOTRANSPIRATION OF APPLIED WATER (see section, "Irrigation Water Use Factors," later in this chapter.)

CHAPTER III

WATER USE AND WATER SUPPLY IN 1980

This chapter discusses urban, agricultural, and other water uses representative of the 1980 level of development in California. These uses are related to water supplies that could reasonably be expected to have been available in 1980[1] under assumed average hydrologic conditions. The discussion covers the following points:

- Factors that influence water use.
- Methods of estimating amounts of water use.
- Changing trends in water use.
- Identification of present water supplies.
- Interrelationships among sources of water and uses of water.
- Summaries by Hydrologic Study Areas of (1) present applied water, (2) net water use, and (3) related water supplies.
- Changes in water supplies and uses since 1972, the base year for the preceding report in this series, Bulletin 160–74.

Steps for estimating how much water is used for crop irrigation and urban purposes are identified in Figure 6.

The section, "Statewide Hydrologic Balance," includes summary tables that provide information on applied water, net water use, water supplies, and a balance of net water use and net water supply.

Agricultural Water Use

California's irrigated agriculture, with more than 200 commercial crops in production, continues to change—in acreages of the various crops, areas where the crops are grown, methods of irrigation, and quantities of irrigation water applied. Of these various changes, the most difficult to determine is total water applied.

California's vast acreages of irrigated lands, numerous water supply sources, and intricate farm irrigation and reuse systems make it impractical to attempt direct measurement of the amount of water used for irrigation, nor are there requirements to report water use, as in some other states. It is, therefore, necessary to use an indirect procedure for calculating this water use. The location and acreage of the various crops grown in an area are determined by land use surveys. Unit water values (that is, acre-feet per acre) are then derived for each crop in the study area. These data provide the basis for calculating the amount of irrigation water application and evapotranspiration of water for each study area and the State as a whole.

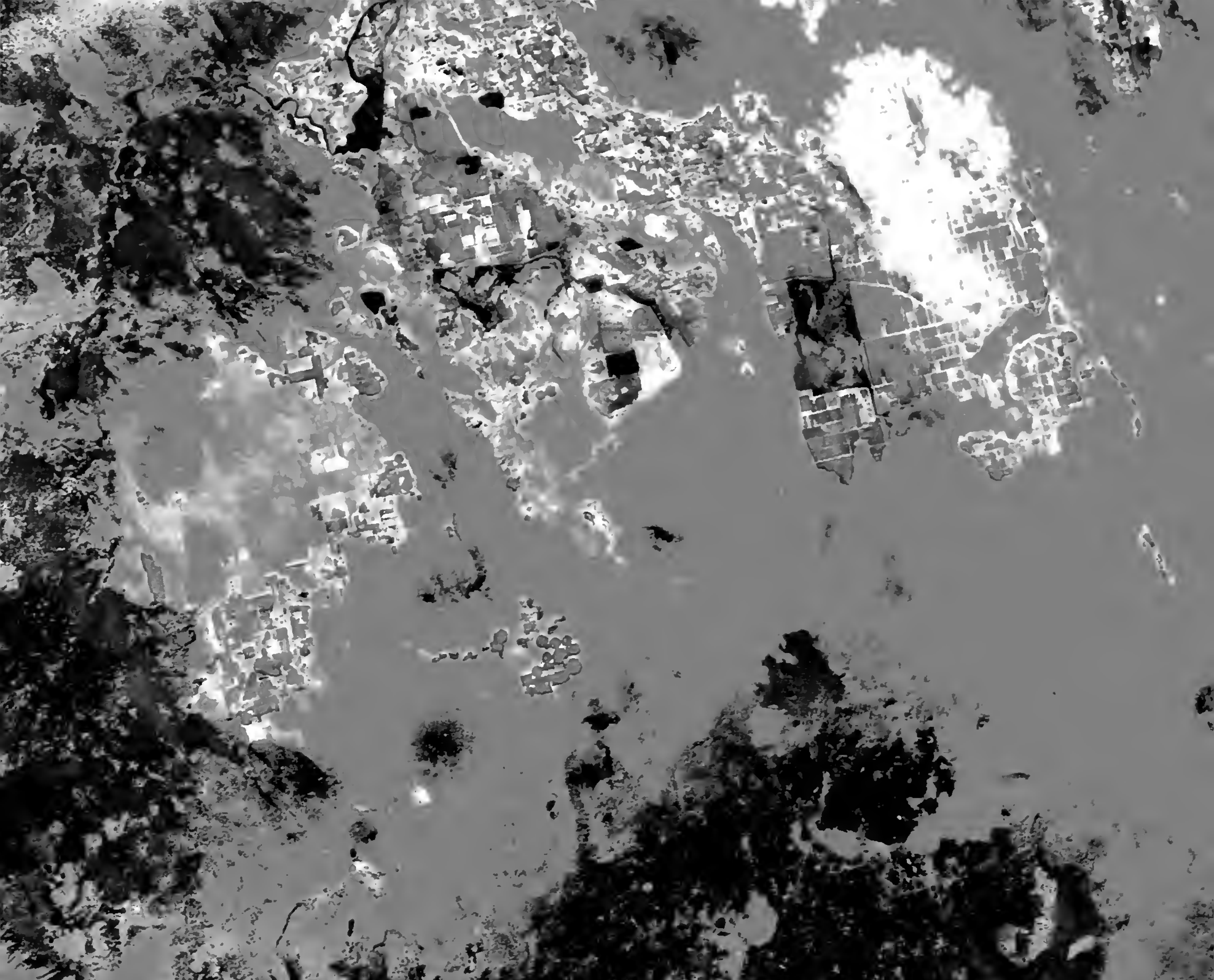
Land Use

The Department has made periodic detailed land use surveys to monitor changes in agricultural crops and urban development throughout the State over the past 30 years. Summary crop acreage information for large areas is generally obtainable from other sources, such as the California Crop and Livestock Reporting Service and the County Agricultural Commissioner's Annual Crop Reports. However, there is no information on the crop locations; this is needed to relate calculated water use to available water supplies. Accordingly, the Department began land use surveys in 1948 and has periodically updated and expanded them since then.

NOTE: References to Hydrologic Study Areas in the tables in this report are indicated by the following abbreviations:

NC—North Coast HSA
SF—San Francisco Bay HSA
CC—Central Coast HSA
LA—Los Angeles HSA
SA—Santa Ana HSA
SD—San Diego HSA
SB—Sacramento HSA
SJ—San Joaquin HSA
TL—Tulare Lake HSA
NL—North Lahontan HSA
SL—South Lahontan HSA
CR—Colorado River HSA

[1] Accordingly, it is an artificial 1980. It compares calculated (not measured) use to water supply, as it would have been if 1980 had been an average or "normal" water year in all locations in the State. For example, in above-normal water years, more water is available, while less water is needed. The reverse occurs in drier years.



This Landsat satellite scene covers the area from Mt. Shasta on the south (lower left) to southern Oregon on the north. Irrigated lands appear as red areas. The circular red shapes at center are fields being irrigated by large center-pivot irrigation systems, which have become popular in northeastern California.

To assess statewide water use and needs for the Bulletin 160 series of reports, the data acquired by land use surveys conducted over a period of years are adjusted to reflect statewide conditions for a single year—in this case, 1980. Comparisons with the 1972 level of development show that many important changes have taken place in both total irrigated acreage and the proportions of individual crops.

Derivation of 1980 Acreage. The 1980 irrigated crop acreages shown in Table 1 were determined by adjusting the Department's land use survey data collected statewide over the last seven or eight years. This adjustment was based on the amount of change between years of survey and 1980, as indicated in reports of the County Agricultural Commissioner and the Crop and Livestock Reporting Service. Information obtained from the Agricultural Commissioners and Farm Advisors was also used in determining the number of acres that are double-cropped in each county.

Principal Changes in Irrigated Land and Crop Acreage, 1972–1980. As shown in Table 1, irrigated land area in California increased from 8,779,000 acres in 1972 to 9,490,000 acres in 1980, an increase of 711,000 acres. Double-cropping increased by 167,000 acres, providing a total increase of 878,000 acres of irrigated crops over the eight-year period.

One reason for this large growth was the increased irrigation of 435,000 acres of grain (oats, barley, wheat, and grain-hay). Much of that increase has been gained by converting previously dry-farmed (nonirrigated) barley land to irrigated wheat, mainly in the Sacramento and San Joaquin Hydrologic Study Areas (HSAs) where rainfall is sufficient to provide acceptable yields of barley but not of wheat. By contrast, in these same areas, irrigated wheat will normally out-produce irrigated barley. Although wheat is a relatively low user of water, the large acreages involved make this change significant in terms of total water use.

The Sacramento HSA showed the greatest increase in irrigated area (about 350,000 acres), due principally to the increase of 180,000 acres of rice and 320,000 acres of grain. Next in significance was the 300,000-acre expansion in irrigated land in the Tulare Lake HSA, where a 500,000-acre increase in cotton took place, the largest change in specific crop acreage in any HSA. Some of the cotton was planted on newly developed land, but most of it was planted to replace such crops as alfalfa, corn, milo, and wheat.

On a statewide basis, one of the most significant changes affecting water use was a 250,000-acre reduction in alfalfa and a 300,000-acre reduction in pasture. These crops are both high water users. The effects of these and other changes in water use are summarized later in this chapter.

TABLE 1

COMPARISON OF IRRIGATED CROP ACREAGE AND LAND AREA BY HYDROLOGIC STUDY AREA

1972 and 1980

(In 1,000s of acres)

Crop	*NC*	*SF*	*CC*	*LA*	*SA*	*SD*	*SB*	*SJ*	*TL*	*NL*	*SL*	*CR*	*TOTAL*
Orchard	9 (15)	10 (24)	44 (54)	66 (61)	54 (64)	61 (41)	286 (294)	341 (318)	445 (371)	— —	2 (3)	34 (34)	1,352 (1,279)
Grapes	28 (10)	27 (11)	54 (20)	2 —	13 (14)	3 (2)	7 (4)	176 (148)	363 (330)	— —	— (1)	10 (8)	683 (548)
Vegetables	18 (20)	15 (16)	286 (236)	51 (57)	21 (28)	18 (27)	140 (109)	146 (209)	153 (122)	— —	2 —	119 (95)	969 (919)
Cotton	— —	— —	— —	— —	— —	— —	— —	197 (119)	1,239 (715)	— —	— —	109 (49)	1,545 (883)
Rice	— —	— —	— —	— —	— —	— —	491 (313)	41 (31)	13 (5)	— —	— —	— —	545 (349)
Grain	80 (73)	5 —	9 (4)	2 (3)	26 (35)	13 (7)	399 (79)	275 (99)	500 (605)	12 (8)	7 (2)	157 (135)	1,485 (1,050)
Other fields	3 (6)	4 (1)	61 (65)	8 (12)	15 (20)	5 (3)	389 (366)	484 (416)	285 (380)	1 —	2 (4)	61 (177)	1,318 (1,450)
Alfalfa	51 (46)	1 (1)	51 (38)	2 (2)	11 (14)	1 (4)	105 (149)	181 (286)	319 (423)	34 (22)	45 (57)	185 (192)	986 (1,234)
Pasture	125 (102)	4 (12)	26 (32)	3 (4)	13 (20)	4 (14)	359 (435)	301 (422)	67 (130)	101 (105)	20 (11)	18 (29)	1,041 (1,334)
TOTAL CROP ACRES	314 (290)	66 (65)	531 (449)	134 (139)	153 (195)	105 (98)	2,176 (1,749)	2,142 (2,048)	3,384 (3,081)	148 (135)	78 (78)	693 (719)	9,924 (9,046)
DOUBLE CROP	— —	2 (2)	72 (40)	16 (19)	6 (10)	5 (10)	92 (19)	80 (19)	72 (65)	— —	— —	89 (83)	434 (267)
TOTAL LAND AREA	314 (290)	64 (63)	459 (409)	118 (120)	147 (185)	100 (88)	2,084 (1,730)	2,062 (2,029)	3,312 (3,016)	148 (135)	78 (78)	604 (636)	9,490 (8,779)

Values for 1972 are shown in parentheses

Rice fields stretch across the Sacramento Valley.

THE SACRAMENTO VALLEY RICE BONANZA

Genetic breakthroughs, improved irrigation and fertilization technology, and development of new and larger markets have brought about burgeoning Sacramento Valley rice acreage. As a result of intensive plant breeding, farmers can select a rice variety that fits a particular farming operation and still meets exacting market demands. Farmers can pick a variety of rice with a short or medium grain and a medium or long growing season and couple these characteristics with short, medium, or tall plant stature. The application of special soil amendments, such as zinc, and the use of more than 200 pounds of nitrogen fertilizer per acre have propelled valley-wide average yields to more than 6,000 pounds per acre, with some rice paddies producing more than 10,000 pounds per acre under ideal conditions.

A decade ago, the rice industry was plagued by a large annual "carryover"; that is, rice that had to be stored for long periods because of slow market demand. Statewide plantings were about 300,000 acres. During the 1970s, plantings fluctuated from year to year, but the overall trend was strongly upward, with rice acreages reaching 550,000 acres by 1980. This up-trend in numbers of acres was also accompanied by an up-trend in yield per acre.

Seventy-three percent of the California rice produced in 1980 was exported to other countries. Of the remaining 27 percent, 10 percent went to Puerto Rico, Hawaii, and Guam; 9 percent went to domestic use; and 8 percent was used for seed and other farm uses, carryover storage, and government purchases.

Rice farming today is a science. The application of precision land leveling has aided in maintaining desired water levels in rice paddies. The use of large quantities of nitrogen, along with careful weed and insect control by herbicides and insecticides, has been largely responsible for the phenomenal increase in yield. Development of short-stature rice has greatly reduced the amount of straw left in rice fields after harvesting. A long-standing practice has been to burn the straw to control pathogens that over-winter there. Air pollution from the burning has long been a problem in parts of the valley. Short-stature rice reduces the amount of straw, which, in turn, reduces by about 50 percent the particulate matter produced by burning it. For more than a decade, the industry has been seeking uses for rice straw that would make its collection economically feasible and thereby make burning unnecessary. Little success has yet been achieved.

Traditionally, rice farmers have irrigated rice by opening the headgate in early May, allowing the water to flow through the rice paddy and spill into drains at the end of the field. Applied water of 9 or 10 acre-feet per acre or even more were common. Today it has been demonstrated that, where soils are sufficiently slow in allowing water to percolate, rice can be grown with 6 acre-feet per acre or less of applied water. Atmospheric losses by evaporation and transpiration are about 3.5 acre-feet per acre, and the balance (2.5 acre-feet per acre) is divided between deep percolation and runoff to surface drains. Nearly all this remainder, of course, is recaptured locally later by pumping from the ground water or from drains. Because about 85 percent of California's rice acreage is grown in the Sacramento Valley upstream from the Delta, relatively little water in the system is actually wasted because runoff is available for reuse either down-slope or downstream and would finally serve the beneficial use of Delta outflow.

While irrigation efficiency on a single farm may be only 50 to 60 percent, overall basin efficiency may approach 80 percent because of the reuse or recycling of water.

Even though California must compete with other nations or other parts of this country that also grow rice, the ability to grow a wide variety of types of rice tailored to fit the demands of a foreign or domestic market gives California growers an advantage. Land suitability and water supply studies indicate that the Sacramento Valley could devote more than one million acres to the production of rice.

Rice production is not without its problems. A source of inexpensive water is essential. Moreover, rice culture is energy-intensive. Large tractors are required to till the heavy clay soil and harvest the crop, sometimes when the land is wet or boggy. Numerous aerial operations are required for planting and applying fertilizer and pesticides, and the harvested rice must be dried, conveyed, and stored. Other problems are air pollution from rice straw burning and public concern over the potential contamination of downstream water supplies by accidental release of herbicides and insecticides in drainage water.

Additional discussion of irrigated land and crop acreage changes is presented in the section, "Summaries of Hydrologic Study Areas," in this chapter.

Factors Causing Changes in Irrigated Acreage and Crop Patterns. Agriculture in California, as well as in the rest of the nation, is influenced by certain basic forces, as shown below.

- Government Policy
  - Foreign trade
  - Crop supports-marketing orders
  - Tax laws
  - Water pricing
- Market Forces
  - Foreign
  - Domestic
- Farm Income
  - Prices received/production costs
  - Management and technological change
- Resource Availability and Costs
  - Irrigable land
  - Money
  - Water supply

Some of these factors influence long-term production trends, while others influence year-to-year decisions. Taken as a group, their overall effect during the past decade has been expansionary, as reflected in the previously mentioned increase of 711,000 acres of irrigated land in California between 1972 and 1980.

Probably the most significant factors have been foreign trade, coupled with large amounts of readily available and affordable ground water supplies. In general, trade agreements with European Common Market countries have had a positive influence. In addition, population growth and increasing real incomes have spurred market development in the Pacific Basin, including the People's Republic of China, Japan, South Korea, Taiwan, and Hong Kong. The significance of this region may be seen in Figure 7, which shows that 70 percent of animal and vegetable products exported to other countries from California in 1979 were shipped to Asian nations.

In 1980, about 30 percent of California's total irrigated area was planted to crops that were subsequently exported. This is shown in Table 2, which shows irrigated acreage required to produce the crops exported. In 1974, exports amounted to 20 percent of total irrigated area. The increase in export production totaled over a million acres, demonstrating a major shift in the relative importance of foreign markets.

The top five agricultural exports from California in 1980 were, in descending order of value, cotton, almonds, rice, wheat, and grapes. The increase in cotton acreage was brought about by worldwide demand and by the rise in the price of synthetic fibers that increased oil prices caused. The opening of trade with China also provided a new market for California cotton. Lint cotton led the exports of California farm products at $1.1 billion in 1980 and represented 28 percent of the total value of all California farm products exported. The major countries importing U.S. cotton were China, Japan, South Korea, Taiwan, and Hong Kong. Almonds, the second leading crop exported from California, represented $430 million, followed by rice at $318 million, wheat at $283 million, and grapes (fresh, raisin, and crushed/wine) at $230 million.

LAND USE SURVEY PROCEDURES

Land use surveys begin with taking vertical aerial photographs. The 35-millimetre transparencies show about one square mile of land at a scale of approximately 1:62,500. They are projected onto a screen, boundaries of fields are interpreted, and, to the extent possible, crops are identified. This information is delineated on U.S. Geological Survey 1:24,000 scale 7½ minute quadrangle maps, which are then taken into the field for positive crop identification for each parcel and the acreage of each crop type by counties, hydrologic areas, irrigation districts, and other areas is then determined. At present, the areas of significant water use are resurveyed, on the average, about once every seven years; that is, each year, each of the Department of Water Resources' four District Offices surveys about one-seventh of its area of significant water use. Other areas in which urban or agricultural water use is low are surveyed only once every 15 years or so.

The Department has been working for more than five years with the National Aeronautics and Space Administration (NASA), the Space Sciences Laboratory of the University of California (UC) at Berkeley, and the Geography Department at UC Santa Barbara in developing technologies to use Landsat satellite imagery to assist these surveys. In 1979, some of these techniques were tested in a statewide survey of irrigated acreage. The exercise demonstrated the technique to be a cost-effective and valuable tool for deriving interim estimates of irrigated acreage between regularly scheduled, more detailed surveys. Identification of specific crops from satellite imagery is much more complex than simply determining total irrigated acreage because California produces some 200 commercially grown crops. The Statistical Reporting Services of the U. S. Department of Agriculture (Washington, D.C. office), the California Crop and Livestock Reporting Service, the California Department of Food and Agriculture, NASA, UC Berkeley's Space Sciences Laboratory, and the Department of Water Resources have agreed to cooperate in further research and development of satellite imagery-related techniques for crop acreage determination.

At present, the cost of borrowing money is a principal concern for farmers. However, such was not the case during most of the period since 1972. Farmers were assisted by low-interest loans from the federal government and tax shelters for significant portions of farm income.

The foregoing factors, combined with the effect of changes in prices received and production costs, are probably best reflected by net farm income. Since 1972, the increase in farm production costs exceeded the increase in receipts in three of the intervening years. However, the overall trend has been increased receipts over costs. The most severe drop occurred during the 1976–1977 drought, but this was followed by a quick recovery in 1978. In 1979, net farm income exceeded three billion dollars for the first time. Recent trends in gross farm income, production expenses, and net farm income are depicted in Figure 8.

Figure 7. DESTINATION OF CALIFORNIA ANIMAL AND VEGETABLE PRODUCTS EXPORTED IN 1979 (In percent of dollar value)

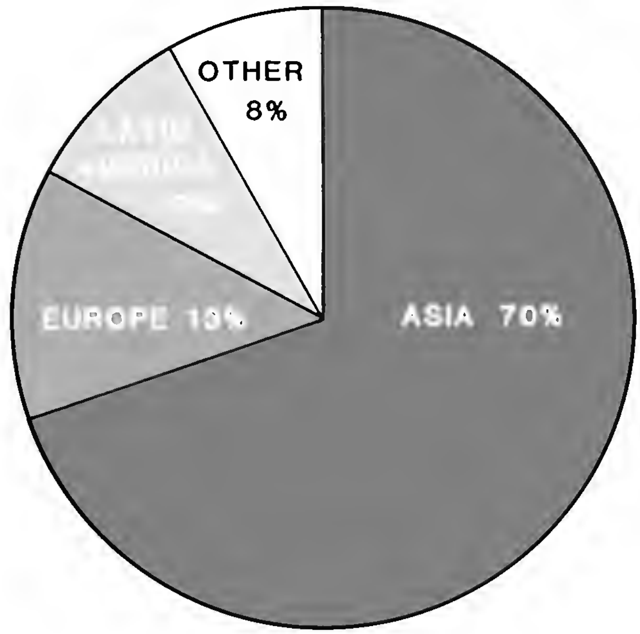


TABLE 2

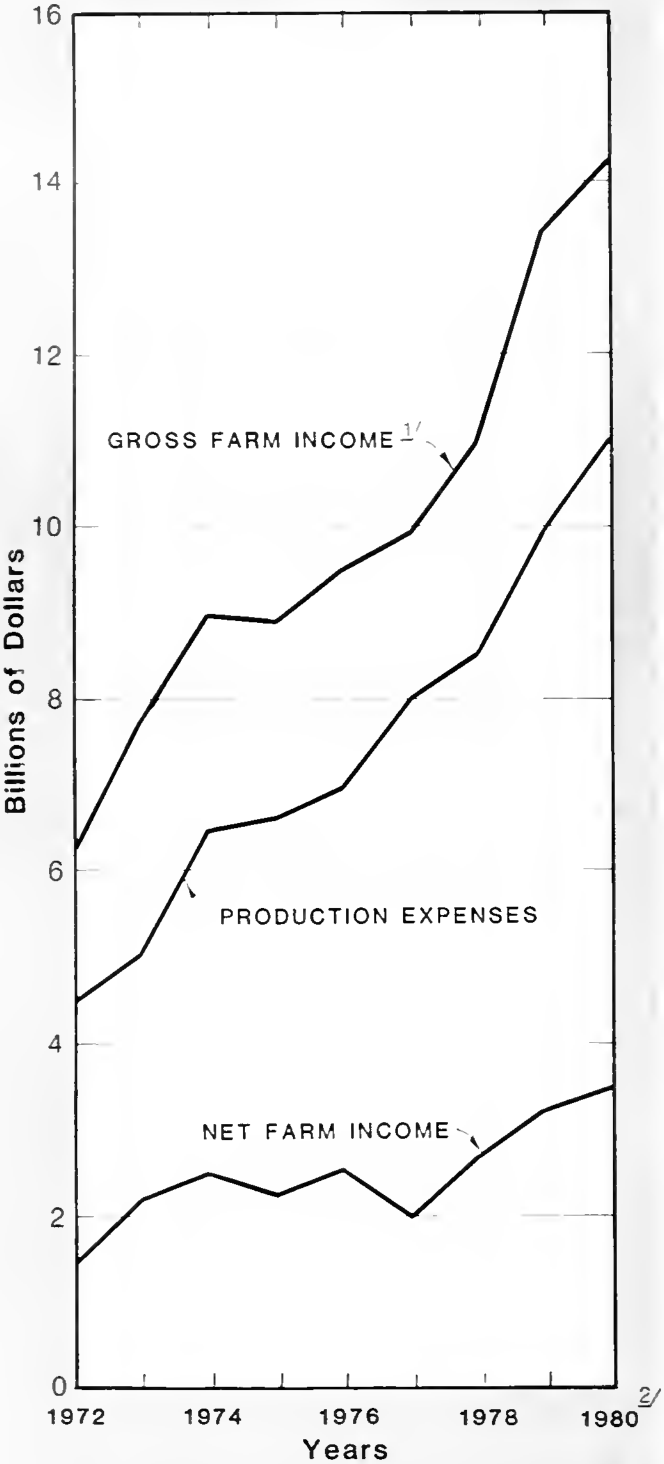
AREA USED TO PRODUCE CALIFORNIA CROPS EXPORTED TO FOREIGN COUNTRIES [1]
1974 to 1980
(In 1,000s of acres)

Crop	*1974*	*1975*	*1976*	*1978*	*1979*	*1980*
Cotton Lint	693	620	840	1,178	1,373	1,433
Wheat	570	801	611	465	668	784
Rice	252	168	163	255	235	314
Almonds	113	156	144	170	264	192
Oranges	43	45	55	45	34	95
Dry Beans	16	11	25	80	68	85
Alfalfa Hay	46	22	44	44	42	63
Grapes	59	91	75	99	86	58
Walnuts	36	42	48	47	36	56
Lemons	16	10	20	16	17	16
Prunes	22	36	25	31	24	23
Lettuce	11	11	11	11	9	8
Peaches	5	6	7	7	9	7
Tomatoes	8	10	11	8	14	10
TOTALS FOR:						
Above Crops	1,890	2,029	2,079	2,456	2,879	3,144
All Crops	2,000	2,100	2,200	2,600	3,000	3,200

[1] Estimated from statewide average yields. Data for 1974–1976 on fiscal year basis. No data available for 1977.

Sources: Annual reports of California Department of Food and Agriculture, California Crop and Livestock Reporting Service, *Exports of Agricultural Commodities Produced in California*, Sacramento.

Figure 8. FARM INCOME AND PRODUCTION EXPENSES IN CALIFORNIA 1972–1980



1/ Includes cash receipts, government payments, value of home consumption, gross rental value of farm dwellings, and income from recreation, machine hire, and custom work.

2/ Preliminary

Source: "California Outlook: Agriculture 1981" Bank of America, May 29, 1981

KEY WATER USE TERMS

APPLIED WATER for urban, agricultural, recreational, wildlife, and other uses is defined as the quantity of water delivered to the intake to a city's water system and the farm headgate, the amount of water diverted from a stream or pumped, in the case of self-developed supplies, and, for wildlife, the amount of water supplied to a marsh or other wetland, either directly or by incidental drainage flows. Because of the large amount of reuse that occurs, the term falls short in describing the amount of water supply needed for water-related purposes over a wide area. For this, the following expression is employed.

NET WATER USE is a term devised to represent the relationship between applied water and the water supply needed for a specific area. It is the measure of the quantity of water that must be developed in or delivered to a service area. The Department of Water Resources defines net water use as the sum of the evapotranspiration of applied water required in an area, the irrecoverable losses from the water distribution system, and the outflow leaving the area. (For a full discussion of the term, see the section, "Net Water Use," later in this chapter.)

EVAPOTRANSPIRATION OF APPLIED WATER (ETAW) is the portion of the evapotranspiration of a specific crop or landscape vegetation supplied by irrigation water. It is computed by subtracting from total evapotranspiration the water supplied to the crop or vegetation by precipitation, including that amount stored in the soil.

EVAPOTRANSPIRATION (ET) is the water taken into the plant, transpired by the foliage, and evaporated from the surrounding soil.

Irrigation Water Use

Three key terms, evapotranspiration, evapotranspiration of applied water, and applied water, are used in describing irrigation water use. A fourth important term, net water use, is used to relate irrigation water use to water supply.

Evapotranspiration. Values for crop evapotranspiration (ET) were developed by the Department of Water Resources and other agencies through applied research conducted at many sites throughout the State.[2] The results of this work reflect the variations in climate and growing conditions prevailing from region to region within California. These differences have great significance in evaluating water use by agriculture. Crop evapotranspiration is a function of time and length of growing season, temperature, humidity, wind, and other factors.

Evapotranspiration of Applied Water. The portion of total ET that is supplied by irrigation is called evapotranspiration of applied water (ETAW). The part of the total precipitation used by a crop

[2] Crop evapotranspiration data gathered in cooperation with other agencies are summarized in *Vegetative Water Use in California, 1974*, Bulletin 113-3, Department of Water Resources, April 1975

(through evapotranspiration) is called effective precipitation. It includes the portion of precipitation that falls during the nongrowing (winter) season and is stored in the soil within the plant root zone and is thus available to the crop during the following growing season, thereby reducing irrigation needs.

With wide differences in ET and effective precipitation that occur throughout California, ETAW for any one crop varies greatly. As Figure 9 illustrates, for alfalfa, ETAW varies from 1.0 acre-foot per acre at Eureka to 6.6 acre-feet per acre in Coachella Valley in Riverside County. ETAW is affected considerably by annual variations in precipitation, and deficiencies in stored soil moisture must be supplemented by increased irrigation.

The effectiveness of precipitation depends on two factors: the specific time the rain occurs and the quantity needed to replenish soil moisture losses. Severe problems arose in 1976 and 1977 because rainfall failed to fully make up for soil moisture lost during the previous years and because of the lack of late precipitation to satisfy spring season growing needs of such shallow-rooted crops as wheat and barley. Where possible, these deficiencies were met with supplementary irrigation to complete the crop growing cycle.

Days of strong, dry winds greatly increase the rate of evapotranspiration and are another factor affecting ETAW. Such winds blew in the Sacramento Valley during the spring of 1976, compounding the effects of inadequate rainfall. To compensate, significantly more irrigation was necessary than would have been needed in a more normal springtime.

Applied Water. Although the ET rate for each crop is relatively constant within a region, irrigation efficiencies range considerably; therefore, the amount of water applied varies considerably. (Irrigation efficiency is computed by dividing ETAW by AW.) Applied water data are assembled by making on-site measurements and acquiring data from other agencies and individuals who also measure water applications. In many cases, however, no measured data are available; therefore, estimates are obtained from knowledgeable individuals. The amount of water applied varies, depending upon such factors as crop ETAW, climate, soil texture and depth, land slope, cost of water, cost of labor, water table depths, leaching requirements, type of irrigation system, and method of operating the irrigation system. Usually some water is applied in excess of ET and leaching requirements (water needed to flush harmful quantities of salt from the surface and the root zone), even in the most carefully managed irrigation system. This is because of:

- The relatively high cost of making precise applications compared to the benefits (which are related to water price).

THE ALFALFA STORY IN NORTHEASTERN CALIFORNIA

Substantial increases in alfalfa acreage have been recorded in northeastern California over the past ten years. For the most part, these increases have occurred because plantings in the Central Valley have declined. Cotton in the San Joaquin Valley is the key to the situation. The demand for cotton has been so great that much of the good-quality row crop land in the San Joaquin Valley has been planted to high-income-producing cotton. Total acreage of lower-income-producing alfalfa, which also competes for the higher quality land, has diminished markedly. This has caused a shift in acreage within California and increased the demand for alfalfa from neighboring Nevada, Oregon, and Arizona.

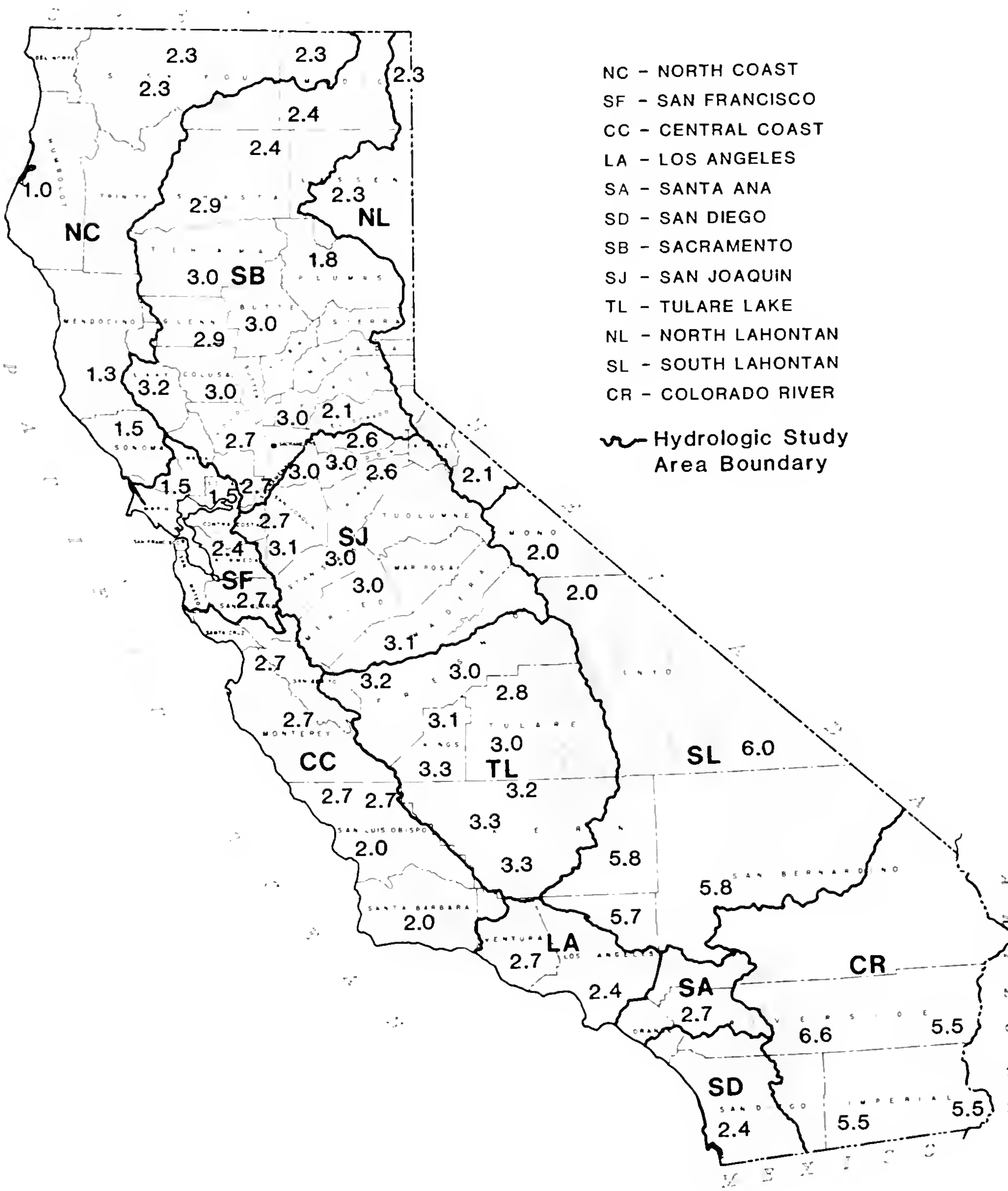
Consequently, areas such as Surprise Valley, Butte Valley, and the upper Pit River basin in Northern California are currently in the midst of an alfalfa boom. These mountainous areas have always been noted for their premium quality hay (high in total digestible nutrients), but they have had to compete directly with the lower quality, but higher yield, harvests in Central Valley areas. Higher-yielding alfalfa varieties and better irrigation techniques have combined to meet increased market demands. New center-pivot and wheel-line sprinkler systems have proliferated, many of these delivering new water supplies from ground water.

Land use surveys during the summers of 1979 and 1980 indicate that more than 80 large center-pivot sprinkler systems—most covering 160 acres, with some to 640 acres—are now operating in the northeastern area. More are planned in the immediate future, particularly around Goose Lake in the North Fork Pit River area. Far more popular, however, are the standard wheel-mounted sprinkler systems that are estimated conservatively to outnumber center pivots twentyfold. Some of the advantages of sprinkler systems, particularly those designed for low pressure (around 20 pounds per square inch), are relatively low costs of maintenance, labor and energy; capability of applying water evenly; and elimination of land leveling, a particularly important factor on shallow soils. Sprinkler systems can also be used to irrigate undulating or steep land parcels.

Since nearly all the existing surface water in these mountain valleys is already in use, farmers have turned to drilling wells or converting meadow pasture served from ditch systems to higher-return alfalfa hay. The following tabulation gives some insight into the direction alfalfa plantings have taken in northeastern California.

	In 1,000s of acres		
Area	*1970*	*1980*	*Change*
Surprise Valley	11.9	16.3	+4.4
Upper Pit River	13.4	29.4	+16.0
Butte Valley	9.4	17.7	+8.3
Total	34.7	63.4	+28.7

Figure 9. AVERAGE UNIT EVAPOTRANSPIRATION OF APPLIED WATER FOR ALFALFA AT SELECTED SITES (Feet)



- The risk of miscalculation when trying to provide only enough for ETAW (which could cause under-irrigation and reduce crop production in the event of unexpected high winds or temperature).
- Factors inherent in the design and performance of the various irrigation systems, including the inability to account for all variations in soil characteristics throughout a field.

Water applied in amounts that exceed the rate of ET is not necessarily lost, however, but may be available for reuse later through percolation to usable ground water or by return flow, which may provide a water supply to down-slope users. This is discussed in more detail in the section, "Net Water Use," later in this chapter.

Recent Trends in Irrigation Systems. Almost 80 percent of California's cropland is irrigated by surface (flood) irrigation systems, such as border, basin, or furrow systems (Table 3). Sprinklers and drip systems have been increasing in popularity, however, because they have characteristics not found in surface methods. This does not mean that surface irrigation is necessarily inefficient by comparison; rather, sprinkler and drip systems usually require less labor and attention to operate at a high level of efficiency. The problem of paying for converting existing systems to newer, more efficient systems has been a deterrent. Improvements in surface irrigation methods have created a potential for increasing water use efficiency, while retaining the advantage of relatively lower installation cost and energy requirements. These improvements include precision land leveling with laser-controlled equipment and systems for recovering and recycling irrigation water after it has been used (pump-back systems).

Highlights of some of the surface, sprinkler, drip, and subsurface systems and their uses are given below. The acreages irrigated by each type of system are given in Table 3.

- **Surface Systems**

  Surface irrigation is used on the major portion of irrigated land—7,800,000 acres—and involves two general types of operation: complete flooding (wild flood, border, and basin) and partial flooding (furrow) of the soil surface. The border strip system, the principal complete flooding method, consists of wide, bordered channels in which the water flows across the field from the water supply ditch to the end of the field in a relatively thin sheet.

  For the level basin system, an area is completely surrounded by a dike and the entire amount of water is applied quickly to the area and slowly absorbed by the soil. Very high irrigation efficiencies with relatively uniform applications can be achieved by this method. Laser-controlled land leveling, which smoothes the ground surface with a precision of less than a one-inch variation in 40 acres, can reduce the quantity of water that must be applied.

  With furrow irrigation, small channels convey the water over the soil surface in narrow, parallel streams. After it has infiltrated the soil, the water

TABLE 3

ESTIMATED CROP ACREAGE IRRIGATED BY MAJOR TYPES OF IRRIGATION SYSTEMS BY HYDROLOGIC STUDY AREA

1980

(In 1,000s of acres)

		Surface Systems						*Sprinkler Systems*				
HSA	*1980 Irrigated Crop Acreage*	*Wild Flood*	*Border*	*Basin*	*Furrow*	*TOTAL*	*Sub-surface System*	*Solid Set*	*Hand Move*	*Mechanical Move*	*TOTAL*	*Drip Systems*
NC	310	25	135	—	5	165	—	25	10	110	145	—
SF	70	—	5	—	—	5	—	40	10	5	55	10
CC	530	—	25	5	310	340	—	55	110	15	180	10
LA	130	—	—	—	65	65	—	10	35	—	45	20
SA	150	—	10	—	15	25	—	—	85	—	85	40
SD	110	—	—	—	5	5	—	50	20	—	70	35
SB	2,180	100	750	410	520	1,780	85	70	170	70	310	5
SJ	2,140	5	860	75	980	1,920	40	65	35	35	135	45
TL	3,380	—	1,000	180	1,450	2,630	—	80	530	50	660	90
NL	150	100	15	25	5	145	—	—	—	5	5	—
SL	80	30	—	—	5	35	—	—	30	15	45	—
CR	690	—	410	35	240	685	—	—	—	—	—	5
TOTAL	9,920	260	3,210	730	3,600	7,800	125	395	1,035	305	1,735	260
PERCENT	100	3	33	7	36	79	1	4	10	3	17	3

No data shown for less than 3,000 acres.

Estimates based upon information provided by the U.C. Cooperative Extension Service. In the case of dual irrigation systems (for example, where sprinklers are used for leaching before planting and a furrow system is used for regular irrigation), only the principal irrigation system is indicated.

moves laterally as well as downward to wet the plant root zone.

To achieve high efficiency with both furrow and border strip systems, care must be taken to stop the flow of water soon enough to minimize the amount that runs off the field or collects at its end. Moreover, the length of the run and the gradient are extremely important in controlling the water to attain percolation into the soil as evenly as possible at both ends of the field. Soil texture and structure are important considerations in designing an efficient furrow or border strip system. In recent times, water recovery (pump-back) systems have gained popularity because they permit the operator to capture and re-apply excess irrigation flows that run off the field from furrow or border strip systems.

Wild flooding is the least extensive and most primitive of the surface irrigation systems. It consists of random spilling of water over the edge of a ditch, with the water flowing over the natural contours of the land. Its only significant use occurs in mountain meadow areas, principally in Northern California.

- **Sprinkler Systems**

There are three types of sprinkler systems: hand-moved pipeline (or hose line), permanently installed (solid-set) systems, and mechanically moved systems.

Wheel-mounted pipelines moved by machine have been used for years throughout the State. Center-pivot sprinkler systems that rotate about a central point (the source of water for the system) have been used only on a limited basis in the Central Valley, but to a much greater extent in the northeastern part of the State. These systems are designed to automatically irrigate a large circular area of a quarter-section or more. Corner swing arms may be added to irrigate field corners that are not otherwise reached in a circular pattern. Of more promise for increased use in the flat Central Valley floor is the recently developed automated linear-move sprinkler system, which moves in a straight line across the field. New designs use computer-controlled tractor units, flexible water supply lines that automatically couple and uncouple to a series of valves spaced along a buried main supply line, and low-pressure sprinkler heads. This system is totally self-contained and is powered by a fuel-efficient diesel generator.

- **Drip Systems**

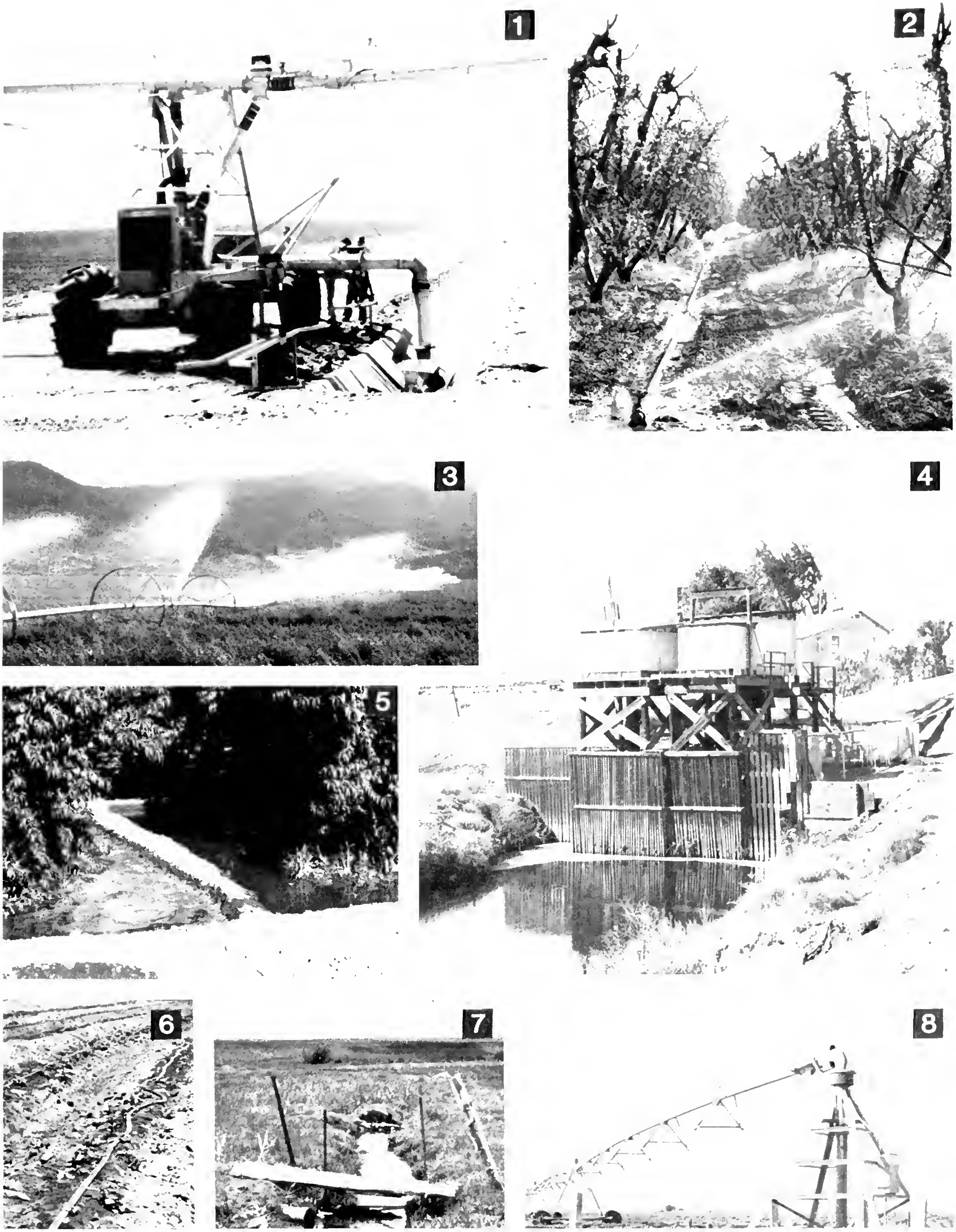
Drip irrigation is now used on about 260,000 acres of irrigated land, and it has been increasing in popularity. Unlike other methods that apply large amounts of water periodically, drip irrigation systems use small amounts of water flowing more or less continuously. The steady flow of drops or dribbles is accomplished by plastic emitters, or a perforated tube, fed with water that has been carefully filtered to prevent the minute orifices from clogging. Drip systems moisten less ground surface area than do sprinkler or surface systems, thereby reducing the amount of water evaporated from bare soil. Although drip systems can be operated at very high efficiencies, the rate of ETAW remains about the same, except for some significant reduction in evaporation from the soil where young trees or grape vines are being grown.

Drip systems are costly to install; however, the use of this system has increased, often where other methods are unsuitable or where water costs are high. An example of both conditions exists in San Diego County where avocados are cultivated on steep, rocky slopes with very expensive water. If other methods of irrigation were used there, runoff and soil erosion would be excessive. Another important area of use is the southern San Joaquin Valley where young trees and vineyards are irrigated by this method. Even where water costs are not high, drip irrigation is of interest to farmers because it offers opportunities to save on labor.

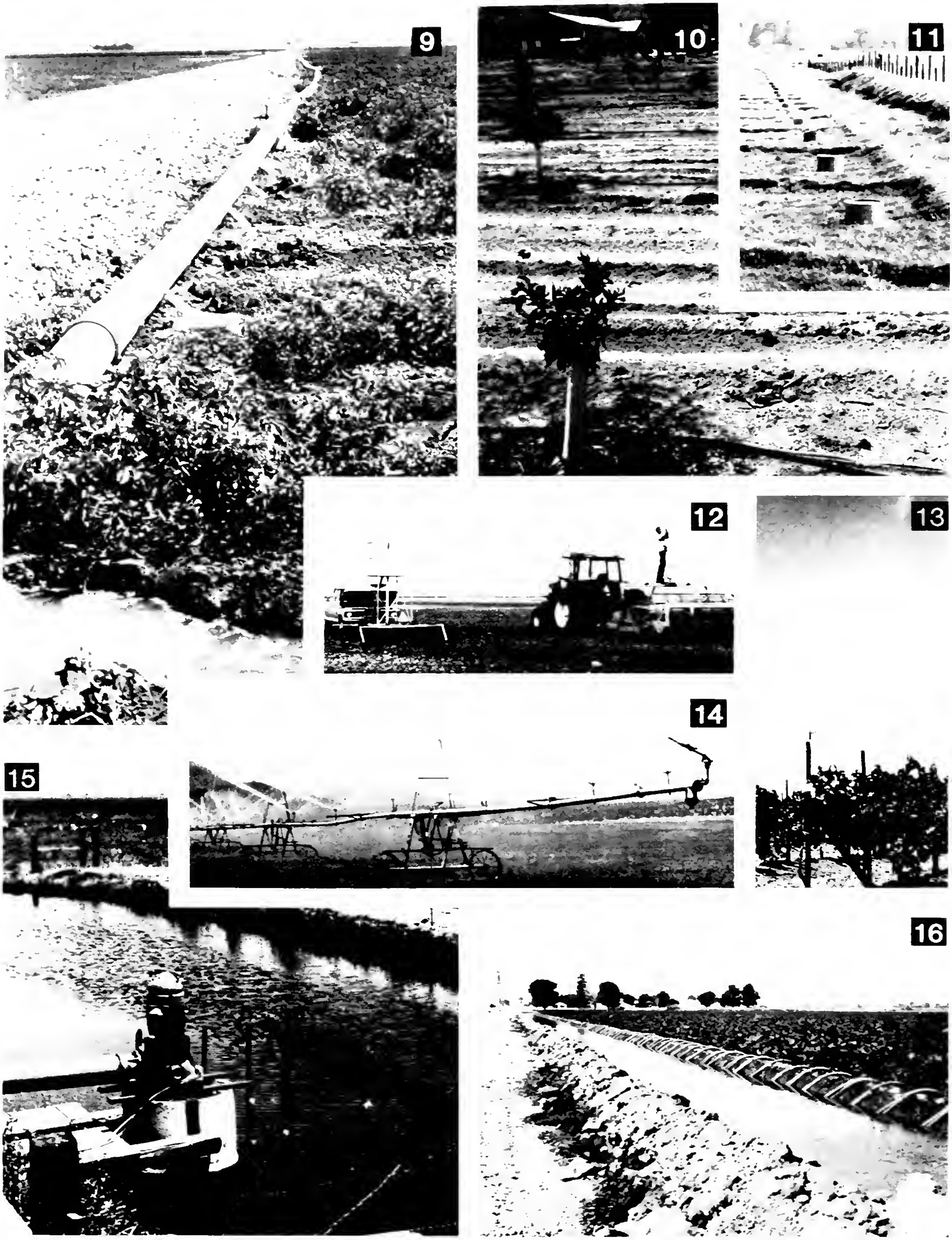
- **Subsurface System**

This is a unique system used only in a very limited area. In much of the Sacramento-San Joaquin Delta, the water level in the channels is considerably higher than the ground surface of the islands. To keep the islands from being inundated, deep drain ditches carry water to pumps that dispose of it into the river channel. To irrigate a crop, the pumps are shut off, which allows the water to rise in the soil. The pumps are then restarted to draw this water below the level of the root zone of the plants.

Agricultural Water Conservation. As used in this report, any increase in on-farm irrigation efficiency is considered water conservation. Whether such action results in a saving of basic water supply depends on the hydrologic characteristics of a particular situation. (This is discussed in detail under "Net Water Use" later in this chapter.) Agricultural water conservation has benefits other than water savings, however. These may include reduced energy use, increased flows in certain reaches of rivers, less need for fertilizer, fewer weed control problems, and, in some instances, increased crop yields.



IRRIGATION METHODS (1) Lineor-move sprinklers. (2) Hand-maved pipeline sprinklers. (3) Hand-moved side-roll sprinklers. (4) Subsurfoce irrigotion. (5) Bosin irrigatian. (6) Drip irrigation by perforated tube. (7) Wild flaading. (8) Center-pivot.



IRRIGATION METHODS (9) Gated pipe furrow system. (10) Drip irrigation by plastic emitters. (11) Border irrigation. (12 Laser-controlled land leveling. (13) Solid-set sprinklers. (14) Mechanically moved side-roll sprinklers. (15) Pump-back system. (16) Siphon tube furrow system.

Urban Water Use

This section describes how urban water use is determined and the historic trends in the factors influencing urban water use.

Estimates of urban water use are based upon estimates of the area's population and representative values for the per capita rate of water use. These values are based on a sampling of water service agencies' records of deliveries, the number of connections served, and estimates of the number of persons per connection. Sample data from individuals who develop their own water supplies are also included. As with agricultural applied water, a portion of urban applied water is evapotranspired, principally by landscape vegetation.

Population

California continues to be the most populous state in the nation, with 23,773,000 people reported in the 1980 census (Table 4). From 1972 to 1980, the State's population grew by more than 3 million, a 15-percent increase, or 1.8 percent per year. The Santa Ana Hydrologic Study Area (HSA) added the greatest number—610,000 people.

Migration. From 1972 to 1980, immigration accounted for 60 percent of California's growth (Figures 10 and 11). Half these people came from the industrialized states of New York, Illinois, Ohio, New Jersey, and Pennsylvania. Two-thirds of the immigrants settled in the metropolitan areas of Los Angeles, San Diego, and south San Francisco Bay. It is also suspected that an additional significant number of undocumented immigrants from Mexico and various countries in Asia were not counted in the 1980 census.

A developing area in Sacramento typifies the urban expansion that occurred in California between 1972 and 1980.

Employment opportunities have been the main force behind this migration influx. While the nation was experiencing employment growth of 3 percent in the nonagricultural sectors, California experienced a 4-percent employment growth (more than 30 percent greater than the nation as a whole). The result was that half the immigrants came to California either for a job transfer, to take a new job, or to look for work.

TABLE 4
CALIFORNIA'S POPULATION GROWTH BY HYDROLOGIC STUDY AREA
1972 and 1980

	Population		*Increase*	
HSA	*1972*	*1980*	*Persons*	*Percent*
NC	363,000	459,000	96,000	26
SF	4,475,000	4,790,000	315,000	7
CC	833,000	1,005,000	172,000	21
LA	7,398,000	7,927,000	529,000	7
SA	2,364,000	2,974,000	610,000	26
SD	1,529,000	2,068,000	539,000	35
SB	1,311,000	1,674,000	363,000	28
SJ	805,000	1,014,000	209,000	26
TL	989,000	1,178,000	189,000	19
NL	44,000	61,000	17,000	39
SL	245,000	303,000	58,000	24
CR	237,000	320,000	83,000	35
STATE TOTAL	20,593,000	23,773,000	3,180,000	15

Figure 10. ANNUAL POPULATION GROWTH BY COMPONENTS

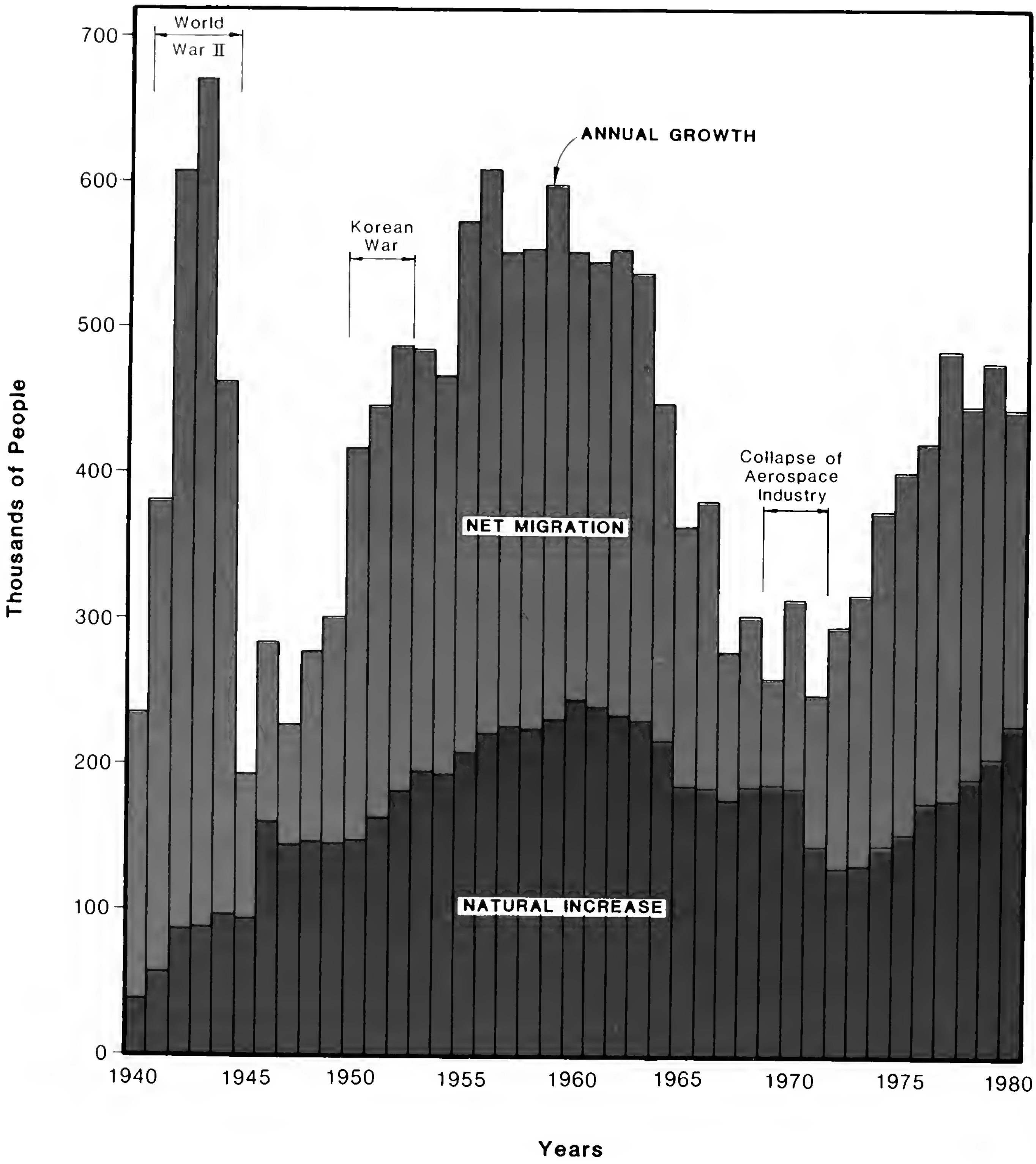
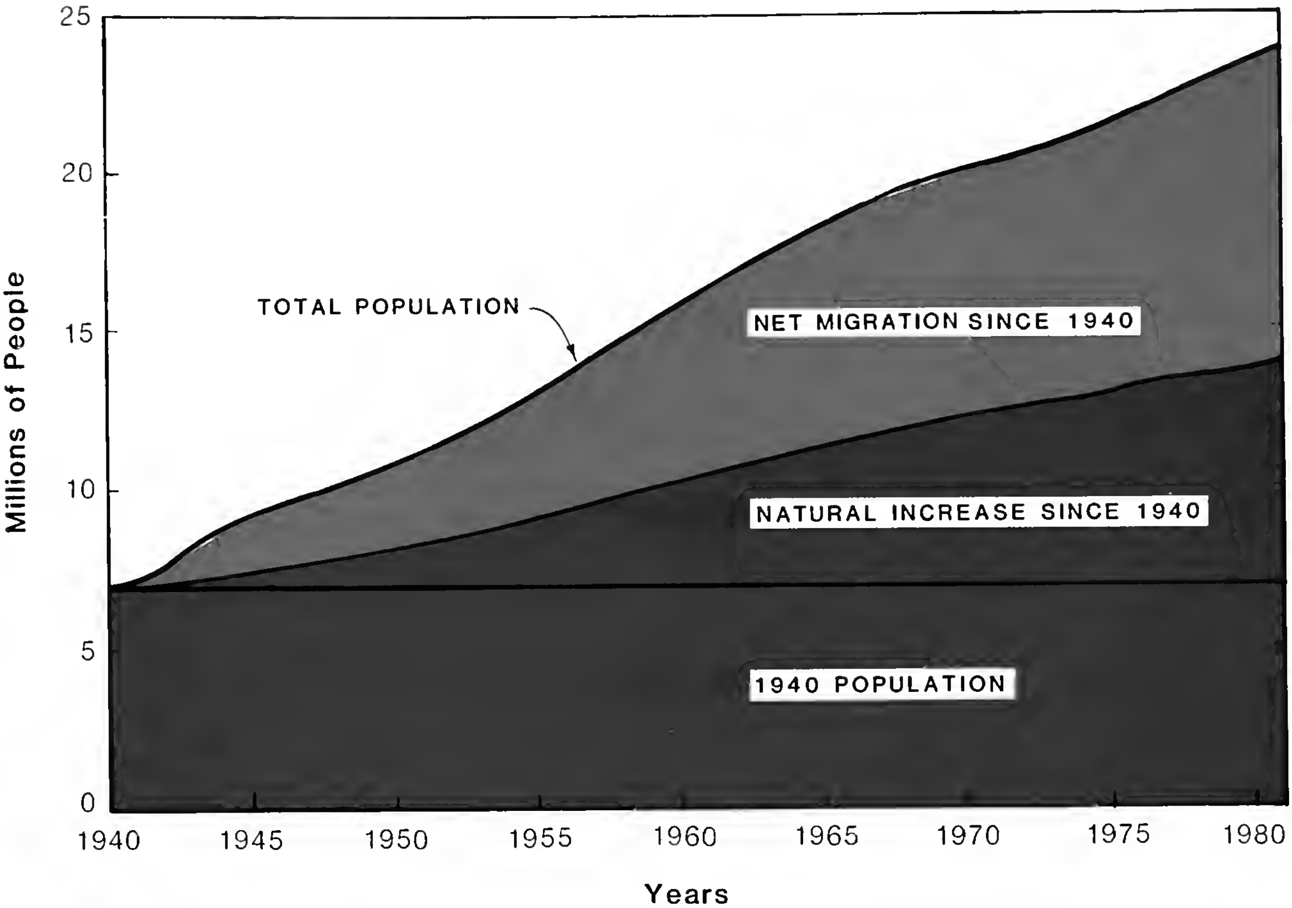


Figure 11. CALIFORNIA POPULATION BY COMPONENTS OF GROWTH

1940 - 1980



Other forces contributing to California's growth from migration have been the greater number of retirees, who are often free to resettle where they wish; greater freedom of movement of families due to the decrease in the birth rates; the increase in the number of women in the labor force; climate; and the desire to be near relatives.

Natural Increase. The remaining 40 percent of California's growth from 1972 to 1980 came from natural increase—births minus deaths. While both the birth rates and death rates have been declining, the numbers of births and deaths have been increasing. The greater number of deaths is attributed to the increase in the number of elderly people. The rise in births results from two factors:

- Women born during the post-World War II "baby boom" who have now reached childbearing years.
- Women in the labor force who delayed marriage and childbearing now deciding to start their families.

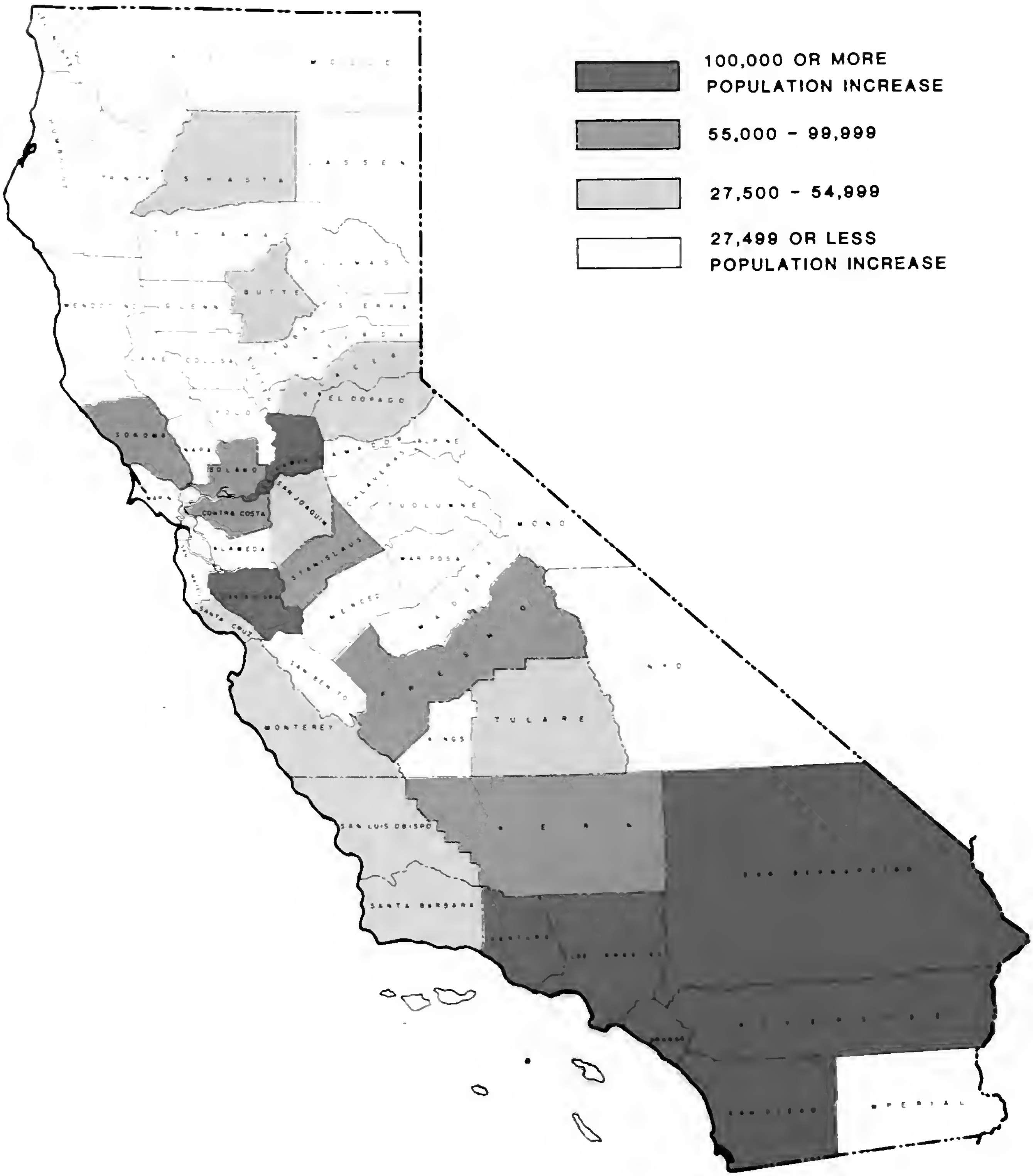
Inter-County Growth Patterns. For the first time since 1850, when California became a state, population in the 50 counties north of the Tehachapi Mountains, which separate the Central Valley from Southern California, grew between 1972 and 1980 at a greater percentage rate than did the eight counties south of the Tehachapis. Since 1970, the northern counties have grown almost 19 percent, and the southern counties by 17 percent.

Migrants to California tend to move first into the metropolitan areas of Los Angeles and San Francisco; but, within a few years, many move to the less congested surrounding counties. Perhaps one-quarter to one-third of the growth in non-metropolitan counties can be attributed to this resettlement to outer suburban areas. The population in counties with commuting ties to the metropolitan areas grew more than population in the more remote counties (Figure 12). The main forces behind the growth in non-metropolitan counties have been:

- The search for less expensive housing.
- The increase in employment opportunities resulting from recent decentralization of employment centers.
- The attraction of coastal, lake, and hill counties.

Figure 12. POPULATION GROWTH BY COUNTY

1972-1980



The 1980 population was based on the census, which tabulated population by county and county subdivisions. The Department then allocated these figures to the appropriate HSA and detailed study areas.

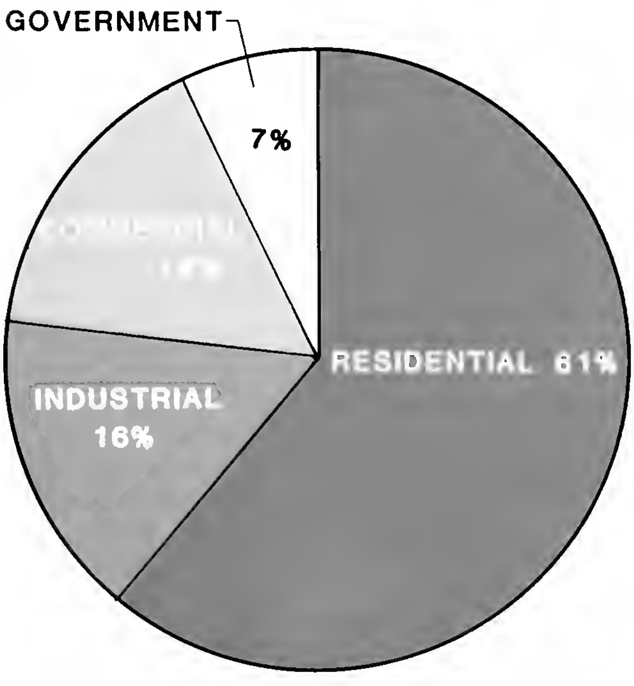
Urban Per Capita Applied Water

The gross per capita urban applied water value is a factor selected to represent total average urban applied water per permanent resident. This value includes residential, industrial, commercial, and governmental use. On a statewide basis, 61 percent of the applied water is residential, 16 percent is commercial, 16 percent is industrial, and 7 percent is governmental (Figure 13).

The gross per capita applied water value is expressed as gallons per capita daily or acre-feet per capita annually. These values are derived from sample data, principally from two sources: water agencies that serve a large number of customers and individual entities that develop their own supply. To calculate urban applied water for a particular geographic area, per capita applied water values derived from data for communities within, or most similar to, the area in question are selected and multiplied by the area's population. Important community characteristics considered are climate, type of housing, housing density, age, industrial activity, and general economic level.

Figure 13. PERCENT OF URBAN APPLIED WATER BY TYPE OF USE

San Francisco, Los Angeles Santa Ana and San Diego HSA'S



Gross Per Capita Use of Agency-Supplied Water. Gross per capita use of agency-supplied water is computed by dividing the total quantity of water supplied to the conveyance system of a water service agency by the number of permanent residents living within the agency's service area. Industrial and commercial water uses are included in the average per capita applied water value derived by this computation method. Large deliveries for industrial or transient recreational purposes will result in higher per capita values. The quantity of water supplied to the conveyance system differs from "water delivered" (a term used to denote the quantity delivered to the users' connections) in that it includes all losses between the point of introduction into the system and the users' connections.

In gathering data from water suppliers, a sampling procedure is employed whereby information on water supplied, number of connections, and population served is obtained from most large water agencies, as well as representative smaller water agencies, throughout the State. The single-unit value that represents average use for a particular study area is computed by weighting the unit gallons per capita daily (gpcd), calculated for each of the suppliers sampled in the area, by the population served by each supplier. When little or no sample data are available for an area (which sometimes is the case for relatively small study areas), values are derived by weighting those obtained from samples of similar areas.

This procedure is not a rigid statistical sampling process because water suppliers are not randomly selected. This is because of the great variation in record-keeping practices by water agencies, a factor that can add greatly to the cost of collecting, augmenting, and processing data from some agencies. Rather than limiting data to a specified preselected sample, all readily obtainable data of acceptable quality are used in the calculations.

California does not require the reporting of water use data to a central State agency, as do many other states, and it becomes necessary to locate individual data sources and obtain and verify these records. Special atttention is given to verifying the "population served" estimate, which is often just a rough estimate by the agency. The Department of Water Resources periodically updates gross per capita applied water estimates on the basis of data from about 175 water service agencies throughout the State. Estimates for selected communities are shown in Figure 14. They range from 553 gpcd in Palm Springs in the Colorado River HSA to 85 gpcd at Pacifica, a largely residential community on the coast south of San Francisco.

Gross Per Capita Use of Self-Supplied Water. Periodic surveys of manufacturing water use are conducted to determine quantities of self-supplied water. The local water agency supplies water to most of

Figure 14. GROSS DAILY PER CAPITA WATER USE FOR SELECTED COMMUNITIES (Agency Supplied Water – 1980)

1/ Water supplied by public water purveyors-additional water may be supplied by indivduals and industries for their own use.

the smaller manufacturing facilities situated in cities; however, larger users located both inside and outside urban areas have tended to develop their own ground water supplies or to divert from local streams as a less costly alternative to purchasing it from a public agency. The surveys are directed principally at water-intensive manufacturing plants, such as canneries, refineries, and pulp and paper mills.

A sampling procedure is used in which readily available data on water use are gathered and averaged by each specific type of industry. In this process, each industry value obtained is weighted according to the number of persons employed. Unit employee use (expressed in gallons per employee working day), averaged from replies from a particular county or study area, is assumed to be typical of all industry of that type in the area. The quality of the computed unit-employee-use data depends on the level of response for each industry type. Where data from certain industry types are deficient or missing for a particular service area, statewide averages are substituted. The sample data for each type of industry in an area are then expanded to represent total use of each type by multiplying the unit employee use by the total number of employees in that industry. Some of the findings of the most recent survey in 1979 are presented in the sidebar, "Industrial Water Use."

Water self-supplied by all types of industry in an area is divided by the area's total resident population and added to the per capita value based on agency-supplied water to obtain the total gross per capita applied water value.

Factors Responsible for Changes in Per Capita Applied Water. Many different factors may influence urban water use, and the effect will vary widely among service areas, depending on local situations. These factors are:

- ***Housing Density:*** Increasing density of residential development is generally associated with a decreasing rate of per capita residential applied water. This results from the reduced amount of landscaped area per capita where lot sizes are small and/or multi-family housing has been developed.

  Single-family construction decreased from about 90 percent of all new housing starts in the mid-1950s to just over 50 percent by the late 1960s. During this same period, multi-family apartment construction increased from less than 10 percent to over 40 percent of all new housing starts. By 1972, multi-family units had increased to 55 percent. However, in recent years, as interest rates climbed, finding financing for the larger, multi-family unit projects has been more difficult, which has caused this type of construction to drop to 44 percent of new housing starts (1980). Numbers of sin-

INDUSTRIAL WATER USE

The Department of Water Resources conducted a survey of 1979 industrial applied water by large-water-use manufacturing plants throughout California, updating information last obtained for 1970. The results of the survey have been published in *Water Use By Manufacturing Industries in California, 1979* (Bulletin 124-3, May 1982). Highlights of the survey of 1979 water use are:

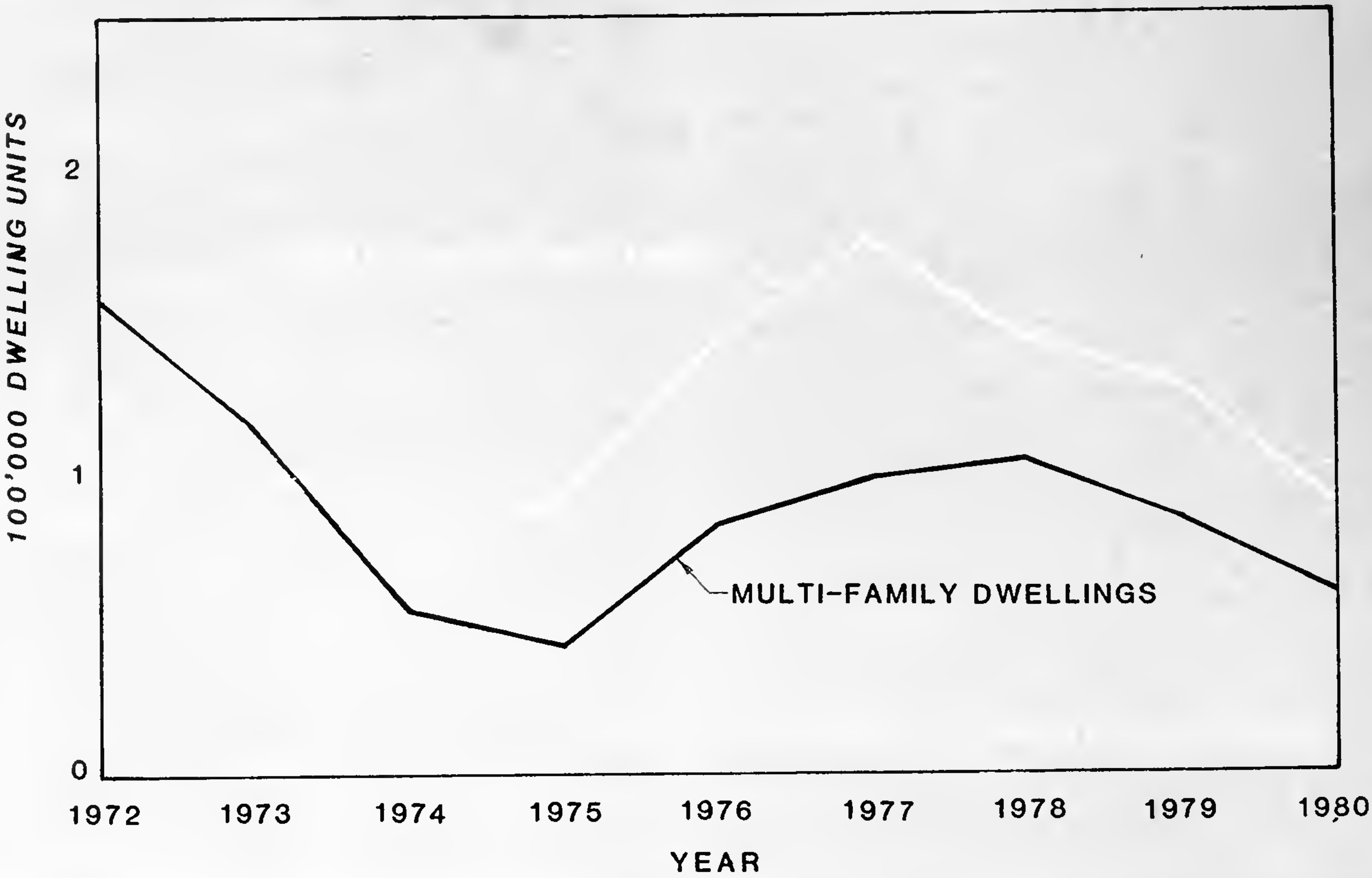
- About 3,000 plants responded, accounting for about 55 percent of the total fresh-water intake by manufacturing industries in California.
- Total water use, based on expansion of sample returns, was about 920,000 acre-feet.
- Some 33,000 manufacturing plants with five or more employees operate in California.
- About 58 percent of the fresh-water supply was reported to have been purchased from water service agencies, and the remaining 42 percent was self-produced, principally from wells located at plant sites.
- Water recycling has increased about 20 percent over the last ten years.
- Los Angeles remains first among the State's 58 counties, with a total annual fresh-water use of 272,000 acre-feet (and first in total number of manufacturing plants). Contra Costa County is second, with an annual use of 89,000 acre-feet.
- Plants with high water requirements are often located near bays, estuaries, or on the coast where large quantities of brackish or saline water are available for cooling. Most of these plants are situated in Contra Costa County. Others are located in Los Angeles, Monterey, Alameda, and San Mateo Counties.
- Brackish water composed 37 percent of the total water intake reported by the manufacturing industry.
- Although most plants require water only for employees' sanitation and drinking needs, process water use is now the major fresh-water application in manufacturing, followed closely by cooling water.
- The food processing industry, the major industrial user of fresh water, uses an estimated 224,000 acre-feet of fresh water annually.
- Second in level of use is petroleum refining, which uses 150,000 acre-feet, followed, in declining order, by lumber and wood products; paper and allied products; chemicals; stone, clay and glass; and primary metals.
- The use of water varies considerably among plants. The discharge-intake ratios vary from slightly more than 0.25 to more than 0.94 for those industries that replied to the questionnaire.
- Total manufacturing water use in 1979 was about 918,000 acre-feet. This is slightly less than the 1970 level, although the number of industrial plants increased by some 4,000. The rates of water use by the various major industries have changed somewhat, with most industries now using less water.
- The industrial sector uses about 18 percent of the State's total urban applied fresh water.

gle-family units have exceeded multi-family units since 1973 (Figure 15).

- ***Water-Using Appliances:*** Following World War II, average per capita residential water use began a steady climb, as automatic clothes washers, automatic dishwashers, garbage disposals, and other water-using appliances were introduced and widely purchased by the public. The use of major water-using appliances may have approached a saturation level in many communities by now.
- ***Persons-per-Household:*** During the 1970s, the population increased 18 percent, but the number of households increased 31 percent. Much of this increase in households can be attributed to the growth in numbers of single-person households arising from higher divorce rates, longer life expectancy, and the postwar "baby-boom" generation's early departure from home and delayed marriage.

  There were 2.9 persons per household in 1970; this figure has now dropped to 2.6. The impact of this change is to increase per capita applied water because some household water uses are somewhat independent of the number of household residents. Landscape irrigation is an example.
- ***Metering:*** Metering of water to customers has a pronounced effect on residential water use. Studies have indicated that conversion from a flat rate to metered billing may reduce water use by as much as 50 percent initially; although this level of reduction commonly is not permanent, use will normally continue to be significantly less than before metering began. Most of the major urban areas of California are already metered; statewide, more than 90 percent of delivered water is metered. The San Francisco Bay, Los Angeles, and San Diego metropolitan areas are almost completely metered; but only about 10 to 15 percent of the Central Valley and upland communities measure water delivered to customers.
- ***Water Costs:*** Escalation of materials and labor costs, extension of service to more distant areas, and, in some cases, necessary development of remote and costly supply sources have contributed to increasing real water costs. Present conditions indicate a continuing general trend toward higher costs of water service. With rising water

Figure 15. TOTAL NEW SINGLE AND MULTI-FAMILY DWELLING UNITS 1972-1980



prices, the customer is becoming more aware of the relationship between amount of use and water cost. An additional impact occurs where sewer service costs are billed on the basis of water used. This is discussed further in Chapter IV.

- ***Climate:*** Statewide, an average of about 47 percent of residential applied water is used for landscape irrigation. The influence of changes in climatological conditions on applied water varies widely, depending on the amount of supplemental irrigation normally required for landscape plant growth and the magnitude and occurrence of climatological extremes.

  An examination of historic data suggests that annual variations in rainfall exert the greatest influence on annual fluctuations in residential water use in California. In some communities, per capita applied water has typically varied inversely with annual variations in precipitation, with landscape irrigation requiring more water in long, dry periods and less in prolonged wet periods. Variations in the growing season rainfall pattern have caused residential use to vary by 25 percent or more. However, in areas where average annual precipitation is less than five inches, water use is only slightly affected by variances in rainfall distribution and amounts.

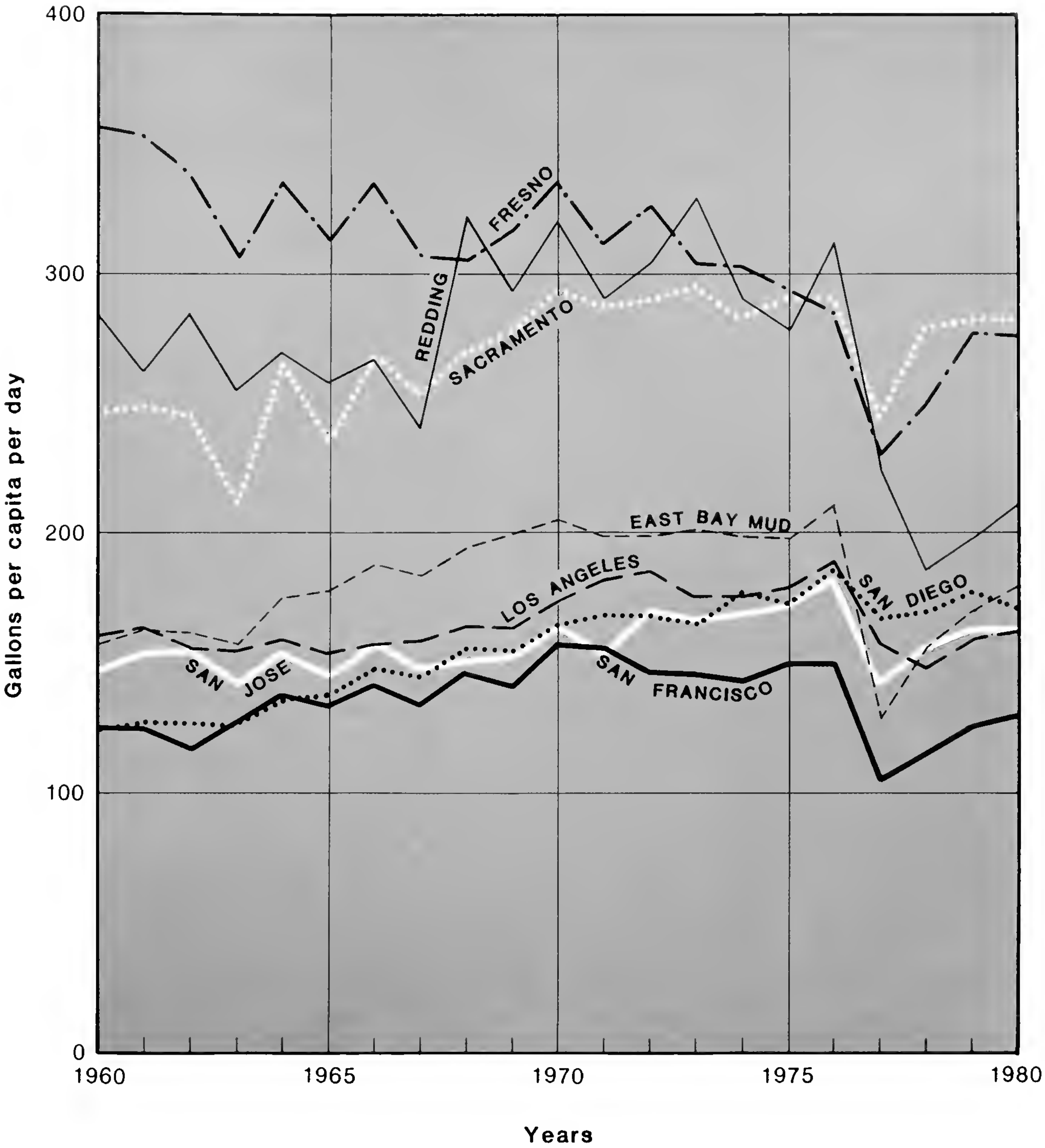
  The patterns of per capita applied water in the several California urban areas shown in Figure 16 illustrate the fundamental divergence in rates of use between inland valley cities and coastal cities, due mainly to differences in climate. High summer temperatures in Redding, Sacramento, and Fresno require much heavier watering to sustain landscapes.

- ***Urban Redevelopment:*** In some cases, extensive urban redevelopment has had a significant local impact on the amount and nature of water use. Usually it reduces use as residences are replaced by commercial, governmental, or light industrial development.

Trends in Gross Per Capita Use

The overall trend in per capita applied water for many cities and regions appears to have been downward or tended to level off over the past decade,

Figure 16. HISTORICAL GROSS PER CAPITA URBAN APPLIED WATER FOR SELECTED CITIES



Water-using appliances such as this automatic dishwasher have contributed to the increase in per capita water use.

although interpretation of the trend line has been somewhat complicated by the 1976 and 1977 drought (Figure 16). During the drought, many communities experienced mandatory or voluntary water rationing. Since 1977, per capita applied water appears to be returning to about the level of use that prevailed just prior to the drought.

Between 1960 and 1980 (excluding 1976 and 1977), calculated trend lines for the communities included in Figure 16 show an overall increase, except in the city of Fresno. However, more years of data beyond the 1976–1977 drought are needed to determine the direction of the long-term trend and the impact of water conservation.

Water Conservation Efforts. In the past few years, water conservation—that is, increased efficiency of use—has become an important consideration in the management of public water and sewerage utilities. The traditional approach to managing utilities was to enlarge the delivery system continually and seek new sources of water as population growth increased use; however, in recent years, water utilities serving growth areas have begun to see water conservation as a way to reduce the immediate need to develop new supplies. In the past, high levels of consumption tended to reduce unit costs for the water utility because of the economies of scale in larger pipelines and more reservoirs and treatment plants. Many water utilities, however, have reached the limit of their less expensive sources of water and must turn to more costly sources of water as use increases. In an attempt to avoid as much of these high costs for as long as possible, many utilities have taken measures to encourage their customers to use less water. These conservation efforts have evidently had an effect on per capita applied water rates in these areas.

Other Water Uses

While irrigated agriculture and urban water use make up the major water uses, there are other important beneficial uses of water. They are discussed in this section.

Energy Production

Water use by oil refineries and supplemental small thermal electric generation plants are included in the estimates of total urban water use. Since all the water is returned later to the stream, use of water by hydroelectric generation plants is included under the "Instream Water Use" section later in this chapter. On the other hand, substantial quantities of cooling water for major inland thermal electric generation plants and water for enhanced oil recovery is consumed, and very little of it is available for reuse.

Power Plant Cooling. Steam electric power plants require high-quality water for steam generation, most of which is recycled continuously and only a small part of which is lost in the process. The high-quality make-up water for steam generation is frequently obtained initially by distillation to remove all constituents that might cause scaling or corrosion of the boiler, or in any way affect the steam generation equipment. Much larger quantities of cooling water are required to recondense the steam for reuse. The

cooling water is either passed through the plant and returned to its source (once-through cooling) or recycled through a cooling tower.

The thermal electric plants located on the coast of California or at its bays and estuaries take advantage of the large volume of cold water available from the ocean for the once-through cooling process. Inland power plants, such as Sacramento Municipal Utility District's Rancho Seco nuclear power plant, use evaporative cooling towers and recycle fresh cooling water until the concentration of total dissolved solids approaches specific waste water discharge quality limits set by the Regional Water Quality Control Board. These limits are designated to protect the quality of the body of water receiving the discharged water.

About 79 percent of the present statewide steam electric generation plant capacity uses once-through ocean-water cooling. Plants aggregating 19 percent of such capacity use cooling towers. Present use of fresh water for cooling is 42,000 acre-feet per year. Existing geothermal plants also employ cooling towers, but they are not included here because their cooling water requirements are met with geothermal steam that has been condensed back to water.

The potential for once-through ocean-water cooling for new electric generating facilities in California has steadily diminished over the last decade. Under the California Coastal Act of 1976, the California Coastal Commission has designated much of the coastline as unsuitable for siting new power plants. When federal lands, urban development, and topographic constraints are considered, only 3 percent of the coastline remains for consideration as potential power plant sites; however, even before the coastal protection movement began, seismic, population safety, and air quality considerations limited coastal siting. The U.S. Environmental Protection Agency's restrictive approach to controlling thermal discharges has further discouraged the use of once-through ocean-water cooling. Forecasts of electrical energy use by the California Energy Commission are now more conservative, so fewer new power plants will be required to meet future energy needs.

Geothermal electric generation is emerging as an important energy source in California. Two types of geothermal resources—vapor-dominated (dry steam) and liquid-dominated (hot water) systems with temperatures above 150°C—are considered economically feasible for commercial electric generation. The vapor-dominated resource has undergone the greatest development. Current production in California at the Geysers in Sonoma County is 908 megawatts, with an additional 326 megawatts under construction. At the Geysers, condensed steam is used in the cooling towers and is sufficient to meet cooling water needs. At present, there are only two liquid-dominated geothermal electric generation plants in California. These are 10- and 11.2-megawatt demonstration projects located in the Colorado River Hydrologic Study Area (HSA). Together they use a total of 3,000 acre-feet per year.

Enhanced Oil Recovery. A large amount of California's oil reserves are extractable only through the use of enhanced oil recovery (EOR). Enhanced oil recovery includes waterflooding and thermal stimulation that forces or improves the flow of oil to production wells. In California, EOR has been used to extend the life of old oil fields and facilitate extraction of California's heavy oils.

Waterflooding is a process in which water is injected into an oil reservoir to increase the pressure and force oil to flow toward the production wells. The Wilmington field in the Los Angeles HSA is the site of one of the largest waterflooding projects in the world. Its yield from waterflood operations has been more than 20 million barrels of oil per year in recent years.

Thermal stimulation, the injection of steam, has also been used for a relatively long time in California, primarily because the more viscous oils flow more readily when heated. The major area for thermal stimulation is the Tulare Lake HSA, where close to 90 million barrels of oil were produced by that method in 1980.

Water uses in HSAs in which onshore oil recovery occurred in 1980 are listed in the following table.

Water Uses for Enhanced Oil Recovery in California 1980 In 1,000s of acre-feet

HSA	*Fresh Water*	*Other Water**	*Total*
Tulare Lake	7	56	63
Los Angeles	2	93	95
Central Coast	7	8	15
Santa Ana	1	26	27

* Production water (water produced along with the oil), sea water, and treated waste water.

Water Quality Control

Actions by the State Water Resources Control Board (SWRCB) in water quality control and related water rights matters have had significant impacts on water use and water supply in the past few years.

Recent water quality control efforts by SWRCB have been notably effective in protecting overall water quality in streams. Improved stream conditions have resulted largely from State and federal laws requiring clean-up of discharges from waste water treatment plants and industries. Municipal waste water treatment plants are eligible for State and federal assistance in complying with strict standards, and some $4 billion in State, federal, and local funds have

PROTECTION OF FISH AND WILDLIFE RESOURCES IN THE SACRAMENTO-SAN JOAQUIN ESTUARY

The Sacramento-San Joaquin Delta, the Suisun Marsh, and San Pablo and San Francisco Bays provide vital habitat for a variety of fish and wildlife. The most significant sport fish are anadromous species—striped bass, chinook salmon, sturgeon, American shad, and steelhead rainbow trout. All these fish spawn in fresh water and spend most of their lives in the lower bays of the estuary or in the ocean. The Delta is an important nursery area for most of these fish. Of the several resident fish that also depend on the Delta, white catfish are a particularly important sport fish.

The Suisun Marsh is a vital wintering area for waterfowl of the Pacific Flyway. Many small mammals and more than 200 species of shore and song birds also inhabit the estuarine marsh habitat. Two endangered species, the California clapper rail and the salt-marsh harvest mouse, and the rare California black rail are indigenous to the marsh.

The Delta and the fish and wildlife it supports contribute significantly to the area's economy. Central Valley rivers supply about 75 percent of California's commercial chinook salmon catch in ocean waters and contribute to both the ocean and inland sport fishery. The average annual commercial catch is about 550,000 fish, which represents an annual return to the industry of about $13.4 million at 1981 prices. The salmon sport fishery was projected to be worth $1.3 million annually in 1970 (1965 dollars). It is undoubtedly worth far more than that today, although no current estimates exist.

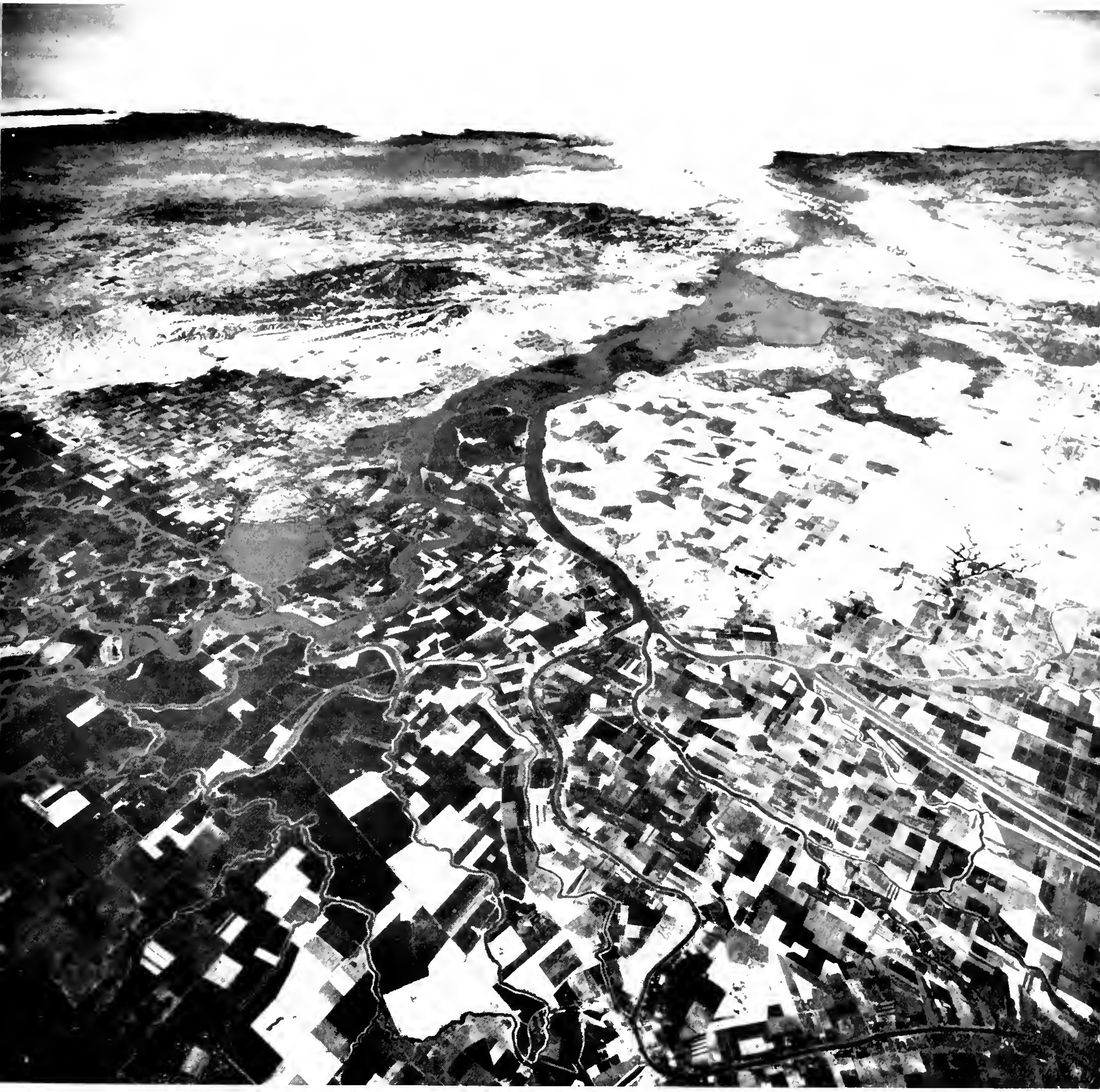
Striped bass have long been one of California's top-ranking sportfish. Significant fisheries also exist for American shad, sturgeon, steelhead, and several resident fish, including largemouth bass and catfish.

The kinds of fish caught in the Delta are very different from those that might have been caught historically. Native species, such as salmon, steelhead, and sturgeon, have been supplemented by such introduced species as striped bass, American shad, and catfish.

Historically, annual runoff from the estuary's watershed varied more widely than it does today. Spring flows were always high, even in dry years, and summer flows were low. In August, for instance, there was almost no outflow from the Delta and salt water intruded farther into the system than it does now. Releases from SWP and CVP reservoirs now ensure outflow and control of salt-water intrusion.

Fish and wildlife studies over the last 20 years have identified major impacts associated with the altered flow regimes described above and the way in which the Central Valley Project and State Water Project are operated in the Delta.

In 1977 the State Water Resources Control Board adopted Decision 1485, pertaining to Delta water rights for the CVP and SWP, which set stringent water quality standards for the Delta and for part of the estuary surrounding the Suisun Marsh. These standards were arrived at after consideration of testimony from local, State, and federal agencies, as well as private conservation groups and individuals. Nearly 15 years of intensive research, a large part of which was financed by the major water development agencies, provided important information. As a result of D-1485, the Department of Water Resources is currently constructing a multi-million-dollar system of water control structures. These are designed to redistribute water from the Sacramento River in a manner that will provide the managed wetlands in the Suisun Marsh with water meeting the D-1485 standards. This system, combined with improved marsh management practices, is intended to protect the marsh habitat.



The Sacramento-San Joaquin Delta, looking west. The wider waterway at center is the Sacramento River, as it meets the San Joaquin River near Antioch. Just above center, the channel narrows as it passes between the Montezuma Hills (right) and the foothills of Mt. Diablo (left). The waterway then opens into Suisun Bay before passing through the Carquinez Straits and San Francisco Bay and finally enters the Pacific Ocean through the fog-shrouded Golden Gate.

been spent since 1972 on the clean-up program. California's industries have also spent large sums of money in reducing discharge of pollutants. Where required by local environmental conditions, municipalities and industries have successfully met more stringent advanced waste water treatment requirements. Additional clean-up measures to control acidic and metallic drainage from abandoned mines and special requirements at high erosion sites and elsewhere have also contributed to improved stream water quality.

In 1978, SWRCB adopted water right Decision 1485, defining water quality standards to protect the Sacramento-San Joaquin Delta and Suisun Marsh. The standards are also included in the Water Quality Control Plan for these areas. The standards are tailored to the hydrology of the area, with less stringent standards in drier years than in wetter years. D-1485 standards are very complicated. Relationships between Delta water quality and Delta outflow have been developed through three decades of prior investigations by the Department to estimate the magnitude of outflow required to satisfy those standards. Applying these relationships to the historic hydrologic sequence of Central Valley runoff indicates that minimum annual Delta outflow required by D-1485 will range from 3 million to 6 million acre-feet and will average about 5.1 million acre-feet per year.

Present average annual Delta inflow is 21.2 million acre-feet per year. For an average water year, 24 percent (5.1 million acre-feet per year) is required as Delta outflow to meet the water quality standards, and another 8 percent (1.6 million acre-feet) is used consumptively within the Delta. Existing storage and export capability of the State Water Project and the Central Valley Project diverts 29 percent (about 6.2 million acre-feet), of which 5.8 million acre-feet is classified as firm yield. The remaining 39 percent (8.3 million acre-feet) flows into the San Francisco Bay as additional outflow.

The Department notified the SWRCB in 1982 that the Suisun Marsh facilities will not be completed by the October 1, 1984, deadline provided in Decision 1485. The current estimate of the earliest possible completion date is October 1987. However, it is proposed to construct the facilities in stages, as an alternative to completing construction by 1987. This will allow the Department to test their performance against model predictions before beginning the next facility. The U.S. Bureau of Reclamation will build its portion as funds and authorization are obtained. The Montezuma Slough control structure will be the first unit of the overall facilities to be built, as originally planned.

TABLE 5

TYPICAL NET DELTA OUTFLOW REQUIREMENTS [1] FOR VARIOUS TYPES OF WATER YEARS (In acre-feet)

Water Year	Net Delta Outflow
Wet	5,800,000
Above normal	5,200,000
Below normal	4,900,000
Dry	3,100,000
Critical	2,800,000

[1] Approximate requirements under 1980 level of development in accordance with water rights Decision 1485.

Decision 1400 of the State Water Resources Control Board pertaining to water rights for Auburn Dam has had no impact to date on water use and water supply because it would apply only after the dam had been built. Because it controls flows only in the lower American River, Decision 1400 would have little overall impact on water supply, in any case. Decision 1422, pertaining to New Melones Dam, has also had limited impact on water supply because it has restricted storage in New Melones Reservoir only from 1979; high inflows during the wet years of 1982 and 1983 negated the storage restrictions. SWRCB has since ruled that New Melones may be filled for power and water because the U.S. Bureau of Reclamation is actively seeking to sign water contracts. During this period, nonstored water has been available for use downstream in the Delta. The practical impacts of D-1422 appear to rest with future court decisions. D-1422 allows storage to satisfy prior rights, water quality flows, and fishery flows, in addition to the federal provision for flood control storage. Water under prior rights in an amount up to 654,000 acre-feet per year is diverted at Goodwin Dam 15 miles below New Melones. The fishery below Goodwin Dam is provided for by releases of up to 98,000 acre-feet per year. The Department of Fish and Game is authorized to test lower flows in below-normal water years. The release schedule is not definite at present; it is subject to studies to be conducted by the Department of Fish and Game.

Fish, Wildlife, and Recreation Offstream Water Uses

Offstream uses of water for fish, wildlife, and recreation take place outside natural stream channels and riparian habitat, such as along canals and drainage ditches. Water used by vegetation (evapotranspiration) that provides wildlife habitat in and near canals and drainage facilities is not available for other uses. Water conservation often includes measures to reduce runoff from farm fields and to prevent seepage from conveyance systems that support this vegetation. The effects of such conservation practices on wildlife habitat should be evaluated before they are implemented.

Urban Parks and Landscaped Recreation Areas. Water used to irrigate lawns and other land-

The irrigated lawn at the entrance to Angel Island State Park is an example of water use in nonurban public parks.

scape vegetation at park and recreation areas may constitute a major local use. Evapotranspiration at these facilities may amount to several acre-feet per acre of landscaping each year. Water use for these purposes is included in the urban water use estimates in this report.

Other Parks and Recreation Areas. Most regional, State, or national park and recreation areas emphasize natural environmental systems and therefore have little landscaping to be irrigated. Water use in such areas is often primarily domestic use by visitors and employees. Planning studies of the Department of Water Resources assume 20 to 40 gallons per person per day for such use. Part of this water is available for reuse, either directly or after reclamation.

Waterfowl Management Areas. Both the California Department of Fish and Game and the U. S. Fish and Wildlife Service manage waterfowl resource areas in California. The federal system totals 230,000 acres in 21 major areas, while the State provides 70,000 acres in 12 major areas for waterfowl management. Some part of these lands is planted to feed crops, and the remainder, in most cases, is marshland.

Wetlands, including marshes, once totaled 5 million acres in California, with 4 million acres in the Central Valley alone. Most of these lands have been reclaimed and converted to other uses. Today only about 250,000 acres of these original wetlands remain in the Central Valley. These wetlands and adjacent croplands provide an important part of winter habitat for 12 million waterfowl annually. The wetlands also provide permanent and seasonal homes for other birds, and for amphibians, reptiles, and mammals. Survival of rare and endangered species such as the American peregrine falcon, bald eagle, California yellow-billed cuckoo, and giant garter snake depends on these wetlands. Wetlands may also improve water quality, recharge ground water, and detain floodflows.

At one time, all wetlands were sustained by seasonal or perennial streamflows. In the Central Valley and the Delta, nearly all major wetlands are now managed for maximum wildlife benefits with water applied directly or incidentally as agricultural return flows.

Some lands other than wetlands are irrigated and crops are grown that will provide habitat for waterfowl, mainly during fall and winter when Pacific Flyway waterfowl are occupying the southern areas of their range. This practice provides alternative food sources, thereby reducing crop depredation by waterfowl on nearby farmlands. Part of the land is used for managed hunting programs. The evapotranspiration of water on major Central Valley wetlands and other waterfowl areas amounts to about 900,000 acre-feet annually. About 250,000 acre-feet occurs in the designated public waterfowl management areas. The remainder is supported by losses from water conveyance systems, agricultural return flows, and other incidental water sources. Some of this water is otherwise unusable brackish irrigation return flows.

Wetlands are essential to the vast waterfowl population that migrates through central California along the Pacific Flyway.

TABLE 6
RECREATION AT SELECTED WATER PROJECTS WITH OVER 500,000 VISITOR-DAYS ANNUALLY
(In 1,000s of visitor-days)

U S Bureau of Reclamation	Visitor-days 1980	U S Corps of Engineers	Visitor-days 1980	State Water Project	Visitor-days 1980	Local Projects with Recreation Grants	Visitor-days 1977
Cachuma	918	Lake Mendocino	2,650	Lake Oroville Complex	811	San Antonio	513
Folsom	1,000	Pine Flat	714	Castaic	1,054	Lopez	500
Natoma	615	Kaweah	682	Silverwood	570		
Shasta	1,300	Success	933	Lake Perris	1,186		
Whiskeytown	800	Isabella	1,489				
Berryessa	891						
Casitas	1,527						
Subtotal	7,051	Subtotal	6,468	Subtotal	3,621	Subtotal	1,013
13 Other Reservoirs	2,392	8 Other Reservoirs	1,834	9 Other Facilities	2,079	27 Other Projects	3,826
TOTAL	9,443	TOTAL	8,302	TOTAL	5,700	TOTAL	4,839

Source Data furnished by agencies responsible for project operation

TABLE 7
PARTICIPATION IN WHITEWATER BOATING AND FISHING ON NORTH COAST WILD AND SCENIC RIVERS

River Segment	*Whitewater Boating (recreation-days)*	*Fishing (angler-days)*		
		Salmon	*Steelhead*	*Juvenile Steelhead*
Smith (entire)	1,000–3,000	11,500	16,600	16,000
Klamath				
Iron Gate to mouth	10,000–25,000	47,000	69,000	90,000
Salmon				
Main	0	0	0	0
North Fork	100–500	1,200	1,200	30,000
Wooley Creek	0	0	0	0
Scott	500–1,000	200	1,000	14,000
Trinity				
Main	5,000–10,000	16,000	13,000	36,000
North Fork	0	0	0	Included with
New River	0	0	0	Trinity River
South Fork	500–1,000		Included with Trinity River	
Eel				
Main	5,000–10,000	5,000	12,500	30,000
South Fork	1,000–2,000	2,700	15,000	40,000
Middle Fork	1,000–2,000	200	1,700	3,500
North Fork	100–500	0	0	4,000
Van Duzen	1,000–2,000	700	3,000	3,000
TOTAL	25,000–57,000	84,500	133,000	266,500

Source: U.S. Department of the Interior, Heritage Conservation and Recreation Service, *Final Environmental Impact Statement, Proposed Designation of Five California Rivers in the National Wild and Scenic Rivers System,* Volume 1, December 1980.

TABLE 8
RECREATION ON SELECTED NORTHERN CALIFORNIA STREAMS

Stream	*Fishing*	*Swimming*	*Boating-Motorized*	*Boating (non-motorized)*	*Picnicking*	*Camping*	*Riding*[1]	*Sight-seeing*	*Other*[2]	*TOTAL*
SURVEY PERIOD: MEMORIAL DAY AND LABOR DAY, 1978[3] **(In user-hours)**										
South Fork American River, Coloma and Lotus	16,000	82,000	—	93,000	53,000	199,000	6,000	7,000	134,000	590,000
Cache Creek, Bear Creek Confluence to Guinda	2,000	32,000	—	44,000	20,000	15,000	1,000	2,000	16,000	312,000
SURVEY PERIOD: MEMORIAL DAY AND LABOR DAY, 1977[3] **(In user-hours)**										
North Fork Feather River, Belden Dam to State Route 70	13,000	9,000	—	1,000	1,000	38,000	1,000	3,000	22,000	88,000
Putah Creek, Monticello Dam to Pleasant Valley Road	58,000	20,000	—	5,000	14,000	3,000	1,000	4,000	21,000	126,000
Tuolumne River in Modesto	6,000	45,000	—	—	25,000	2,000	1,000	4,000	36,000	19,000
SURVEY PERIOD: JANUARY–DECEMBER, 1980[4] **(In user-hours)**										
Sacramento River, Keswick to Courtland	1,890,000	437,000	548,000	259,000	288,000	249,000	40,000	16,000	1,073,000	4,800,000[5]
SURVEY PERIOD: MARCH 1978–MARCH 1979[6] **(In visitor-days)**										
Lower American River	380,000	380,000	56,000	400,000	204,000	—	296,000	532,000	1,628,000	4,000,000
SURVEY PERIOD: OCTOBER 1979–SEPTEMBER 1980[7] **(In visitor-days)**										
Middle Fork Feather River	18,000	11,000	—	1,000	2,000	23,000	11,000	41,000	39,000	146,000

[1] "Riding" includes horses, bicycles, motorcycles, and off-road vehicles.
[2] "Other" includes relaxing, photography, nature study, golf, games, jogging, end walking.
[3] Source: DWR Technical Information Report "River Recreation Activity Survey Data of Selected Northern California Streams During 1977 end 1978", February 1979.
[4] Source: DWR Northern District Report (Review Draft), "Secremento River Recreation Survey", December 1981.
[5] The total Sacramento River use count of 4,800,000 recreation hours translates to 2,000,000 visitor-days.
[6] Source: Secremento County, Department of Perks and Recreation, interview
[7] Source: U.S. Forest Service, Plumes Netionel Forest.

Figure 17. STREAMFLOW DIVERSION SITES WITH AGREEMENTS FOR FISH FLOW RELEASES

Many privately owned holdings are managed entirely or in part to attract waterfowl during the fall and winter hunting season. These areas—collectively known as duck clubs—comprise an estimated 417,000 acres of land in California. In addition to providing a great deal of waterfowl hunting for their owners or members, these clubs provide a significant amount of critically needed waterfowl wintering habitat and feed. The Department of Fish and Game considers them a strong, positive force in management of the resource.

The public waterfowl management areas and private duck clubs are similar in their general management and water use. They are usually planted, at least in part, to a crop requiring irrigation that will have value as food for ducks and geese. For the private duck club land, the evapotranspiration associated with this crop is included in the estimates of agricultural water use in this report. Sometimes the duck clubs can include the production of a cash crop or livestock grazing in their operations. In the fall, at a time planned to coincide with the arrival of the migrating birds, much of the available non-wetted land is flooded to increase its attractiveness to the birds. Due to the time of year, evapotranspiration losses are assumed to be minimal.

Fish, Wildlife, Recreation, and Hydropower Instream Water Uses

Instream water uses relate directly to natural stream channels and their associated riparian vegetation. The major uses in this category are fish, wildlife, recreation, and hydroelectric energy generation. Water is required to support such uses, but, with the exception of riparian habitat, these uses do not significantly deplete streamflow. They may, however, compete with other potential uses that require diversion from the stream. The water that riparian vegetation takes up through evapotranspiration represents a streamflow depletion that is accounted for in the determination of water supply; therefore, this use is not included in the water use tabulations in this report.

Water is of such fundamental importance to fish, wildlife, and recreation that these resources and activities are found in almost all water environments. Water flowing in streams bordered by vegetation creates one of the most attractive and productive settings for fish, wildlife, and recreation. When water is impounded in reservoirs, it also attracts numerous users of these resources. In fact, some of California's major producers of water recreation benefits are its large water supply reservoirs.

Water conveyance facilities are also attractive to recreationists and can provide habitat for fish and wildlife. No large aqueduct system in California is without a fishing access program, and several aqueduct rights-of-way have been improved to provide safe routes for bicycle riding and hiking.

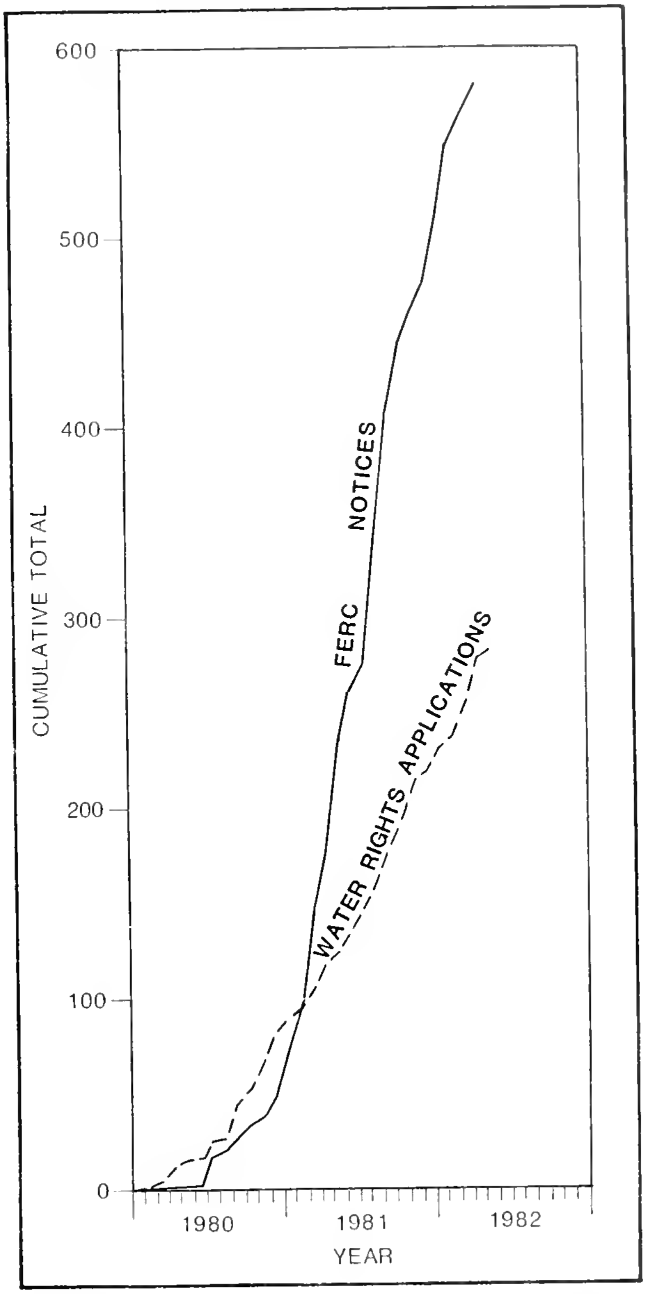
Protection of Instream Water Uses. The State Constitution and the State Water Code both recognize that fish, wildlife, and recreation are beneficial uses of water. The Water Code specifies that these uses be considered before issuing water right permits or making water quality control and other administrative decisions that could adversely affect fish, wildlife, and recreation. The State Fish and Game Code declares that protection and conservation of fish and wildlife resources are of utmost public interest, and recognizes the importance of commercial and sport uses, as well as esthetic, scientific, and educational uses.

State and Federal Wild and Scenic Rivers Acts have been enacted to control development and protect instream uses and other environmental uses. The rivers covered under these acts are depicted on Plate 1.

Water of adequate quality that is released in sufficient quantity and at the proper time is critically important to streamflow for fish, wildlife, and riparian vegetation. Until recently, the importance of maintaining adequate streamflows and water quality for fish and wildlife was often not given sufficient recognition. Even when these factors were considered, the effort sometimes failed because of inadequate knowledge of the ecosystem. The Department of Fish and Game has negotiated streamflow agreements throughout the State. Most have been north of Bakersfield in the Sierra Nevada and the Coast Range (Figure 17). The agreements reflect the water that has been specifically allocated by the State Water Resources Control Board and the Federal Energy Regulatory Commission to instream and offstream water needs, as determined by both agencies at the time the permit terms are established. The streamflow allocations have often proved to be less than the amount necessary to maintain fish life at preproject levels. This is particularly true for permits issued before 1960, which were established when less weight was given to instream uses and less was known about instream requirements. However, in some cases, hatcheries are provided to mitigate the loss of habitat.

Hydropower Projects. Since 1980, there has been a rush to file for development of small hydropower generation facilities throughout the country, particularly in California. This activity is motivated largely by changes in federal law that require electric utilities to purchase power from small power producers at rates equal to the cost of the most expensive power the utility produces or obtains from other sources (avoided cost). In California, this purchase rate is based primarily on the cost of burning imported oil to generate electricity; thus the potential rate of return for small hydropower investors is great. In addition, recent changes in federal tax laws encourage investment in small hydropower facilities. Most of the proposed projects in California are small facilities with a capacity of 5 megawatts or less.

Figure 18. NUMBER OF FERC NOTICES AND WATER RIGHTS APPLICATIONS FOR HYDROELECTRIC PROJECTS SINCE JANUARY 1980



Small hydropower proposals come in the form of applications for State water rights permits and Federal Energy Regulatory Commission (FERC) permits. These applications increased dramatically in 1981. Figure 18 shows the frequency of filing for both permits since January 1980. The large number of applications submitted for these projects (generally five megawatts or less) also spawned considerable interest in examining their potential environmental im-

pacts. The Department of Fish and Game and others have expressed concern regarding cumulative impacts of construction and operation that would be caused by many small hydropower projects—particularly impairment of flows in sections of streams, changes in stream hydrology caused by changes in the time and duration of flow, and sharp reductions in flows needed to flush and otherwise maintain gravels. Proposals for projects on river systems that support anadromous fisheries have raised the most questions.

Net Water Use

Both the derivation of net water use and the distinction between net water use and applied water are important in evaluating various aspects of water use. To understand the impact of applied water for the various uses discussed in the preceding sections on existing water supplies, the substantial amount of reuse and depletions that take place in most situations must be considered. This is important not only in comprehending how present needs are being satisfied, but also the impact that increasing the efficiency of water use (water conservation) may have on the amount of water supply needed.

The basic water supply information available for analysis is expressed in terms of streamflow, stream diversion, yield of surface water reservoirs, ground water pumping, and ground water levels. The expression of water use that most directly relates to these data elements has been termed "net water use." The purpose of computing net water use is to determine the amount of water supply needed in an area to support all uses in that area—residential, agricultural, industrial, and others. Net water use in an area is the sum of the water depletions within the area, plus outflow from the area. Water depletions include crop ETAW (evapotranspiration of applied water), evapotranspiration and evaporation of water associated with the water supply and drainage systems, and other irrecoverable losses, including water percolating to unusable ground water.

The quantity of outflow from an area is a function of the water distribution system and on-farm irrigation practices in the area. Except where the outflow goes into a salt sink (such as the ocean), it usually constitutes a part of the water supply to downstream users. Tightening of water distribution system operations and increased on-farm irrigation efficiency may reduce outflow and total net water use for the area; however, in many notable cases in California, this does not reduce the total quantity of net water supply needed because equivalent quantities from other sources are required to replace the reduced outflow that no longer supplies downstream users. However, energy savings, water quality improvements, and instream flow increases may occur. Generally speaking, net water use is less than total applied water by the amount of excess applied water that is reused within the area. This is demonstrated in Figures 19 and 20.

In Figure 19, total applied water is the sum of the water (157 units) applied to Farms "A" and "B", to the wildlife area, and that which is delivered to the city. The total amount of water reused (57 units) consists of (1) surface return flows (45 units) from Farm "A", the wildlife area, and the city; and (2) the pumping of water that has percolated to ground water (12 units) from Farm "A" and the city. The resultant net water use in this example is 100 units (157 units of total applied water less 57 units of total water reused). The 10 units of outflow from the service area will be part of a prime water supply to a downstream user.

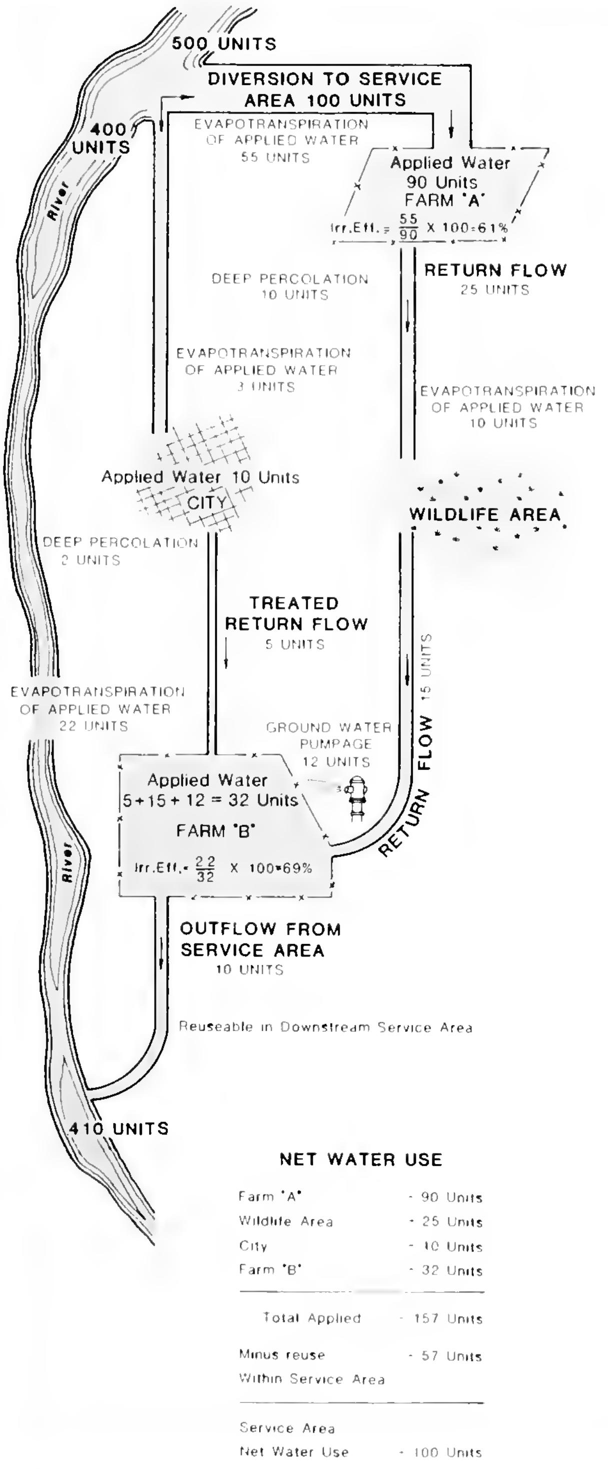
An effect of agricultural water conservation (increased on-farm irrigation efficiency) can be observed by comparing Figures 19 and 20. In Figure 19, the irrigation efficiency of Farm "A" is 61 percent and of Farm "B" is 69 percent. If, through conservation efforts, both farms were to increase their irrigation efficiencies to 75 percent, then the results would be as shown in Figure 20. Farms "A" and "B" would apply 73 and 29 units of water, respectively, for a total of 102 units (down from the 122 total units they applied in Figure 19). The 97 units of water diverted from the river (net water supply) is in balance with the 97 units of the net water use. This compares to the 100 units of diversion and the 100 units of net use shown in Figure 19. Net depletion of river flow downstream from the return flow site would be the same in both examples, 90 units. A major benefit would be the additional 3 units of water in the river between the diversion and return flow sites. To keep the maximum amount of water in the river for instream benefits (without reducing offstream benefits), the return flow from Farm "B" would be only the water required to leach salts from the soil.

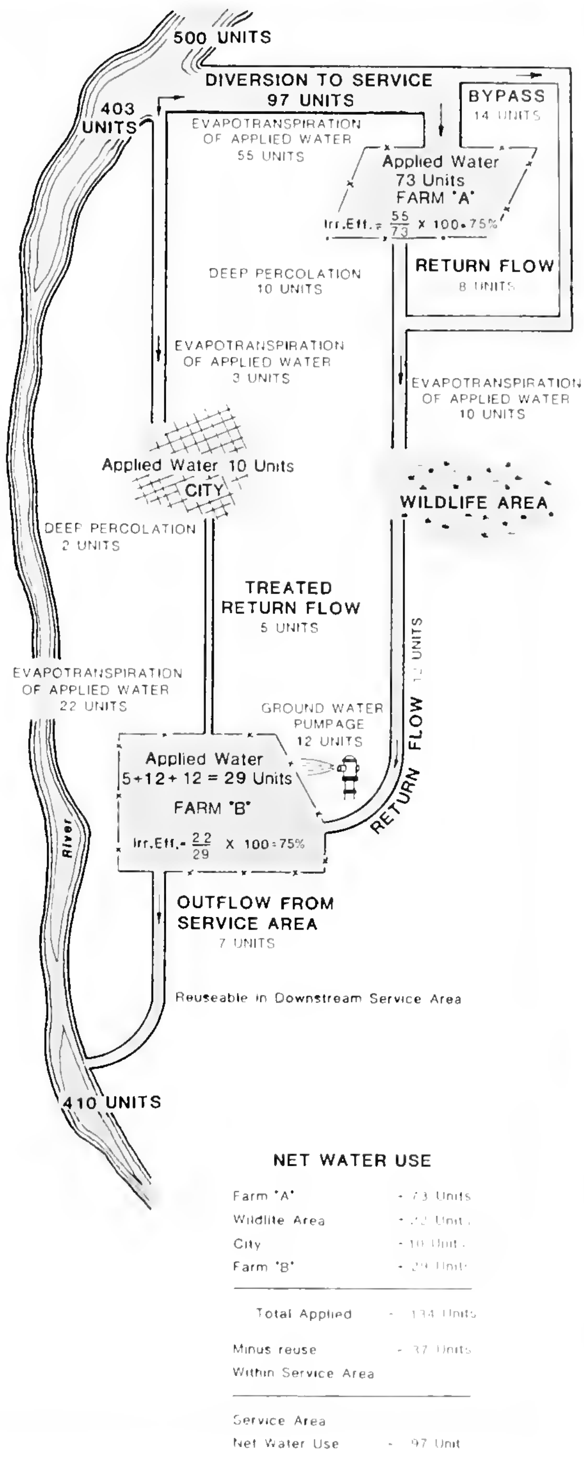
These examples also demonstrate that reductions in quantities of on-farm applied water may increase farm irrigation efficiency, but they do not necessarily save any water, viewed from a service area or hydrologic area standpoint. All that might differ is the routing of water through or around a given service area. However, in some cases, a portion of the return flow moves into a saline drain or percolates to salty or otherwise unusable ground water basins, thus eliminating or greatly reducing opportunities for reuse.

Although greatly simplified, the foregoing discussion illustrates situations typical of most Hydrologic Study Areas and their subunits in California. One significant item has been omitted from the examples—irrecoverable losses from the water distribution system. These consist of losses experienced in bringing

Figure 19. DERIVATION OF NET WATER USE

Figure 20. EFFECT OF IMPROVED IRRIGATION EFFICIENCY ON NET WATER USE





the water to the point of use and losses within the area by evaporation from water surfaces and evapotranspiration by natural vegetation growing along ditch banks and fringes of fields. These losses add to net water use for the area. Part of the total irrecoverable losses from the distribution system is composed of losses experienced in conveying water from one study area to another. In the tables in this report that present agricultural, urban, and other net water use, these additional losses are identified as "conveyance losses."

The handling of waste water reclamation represents a modification of procedures generally employed in computing other types of reuse. In the examples in Figures 19 and 20, treated waste water was considered as reuse of a return flow (incidental reclamation) that was used by Farm "B". However, deliberately reclaimed municipal and industrial waste water for a specific purpose would be considered as a new supply, rather than reuse. For example, if Farm "B" had a contract with the city for the 5 units of reclaimed water, this water would be counted as a new supply and the 5 units of reclaimed water would be added to the 100 units of net water supply, giving a total of 105 units. The 5 units would also be subtracted from the total reuse of 57 units (Figure 19), leaving instead 52 units of reuse.

Net water use in an area is normally somewhat less than total applied water; however, where conveyance losses are relatively large and reuse is small, net water use can exceed applied water. The Colorado River HSA is one such example. Conveyance losses from the All-American Canal occur before the water in transit reaches the service areas in the Imperial and Coachella Valleys and these are lost to the system; reuse of irrigation water in this region is limited because excess applied water either percolates to saline ground water or runs off into drainage ditches, carrying highly saline water from subsurface drainage systems. In this region, applied water in 1980 was 3,650,000 acre-feet, including the reuse of 90,000 acre-feet. Conveyance losses were 540,000 acre-feet. This resulted in a net water use of 4,100,000 acre-feet.

Net water use by Hydrologic Study Areas is shown in tables in the "Statewide Hydrologic Balance" section of this chapter.

Present Sources of Supply

In an average water year, about 75 percent of California's present net water use is met from regulated surface water supplies and direct diversion from streams. An extensive network of local, State, and federal storage reservoirs provides a significant degree of regulation on most streams in the Central Valley and those coastal regions that have been highly developed. At present, there are 450 reservoirs in California having a storage capacity of 1,000 acre-feet or greater. The sources and amounts of surface and ground water being used at the current (1980) level of development are identified on a statewide basis and by HSAs under "Statewide Hydrologic Balance" later in this chapter. Major surface water supply and conveyance facilities are shown in Figure 21 and listed in Tables 9 and 10.

Generally speaking, water supplies are available for present needs in all areas of the State, except in periods of drought. In some local areas, a full irrigation supply is not available in years of below-normal rainfall. Some foothill and coastal communities also experience shortages during these periods. However, present needs in some areas are being met by overdrafting the ground water reservoirs. The average rate of overdrafting of ground water supplies under 1980 conditions of development is 1.8 million acre-feet per year. This rate has been as high as 2.2 million acre-feet (1972), but, with the use of SWP surplus supplies, when available, the rate has been reduced.

IDENTIFICATION OF OWNERS OF RESERVOIRS AND AQUEDUCTS LISTED IN TABLES 9 & 10

DWR	California Department of Water Resources
EBMUD	East Bay Municipal Utility District
HSVID	Hot Springs Valley Irrigation District
KCWA	Kern County Water Agency
LADWP	Los Angeles Department of Water and Power
MCFCWCD	Monterey County Flood Control and Water Conservation District
MID	Merced Irrigation District
MWD	Metropolitan Water Distict of Southern California
OID-SSJID	Oakdale Irrigation District—South San Joaquin Irrigation District
OWID	Oroville-Wyandotte Irrigation District
PCWA	Placer County Water Agency
PGandE	Pacific Gas and Electric Company
SCE	Southern California Edison
SCVWD	Santa Clara Valley Water District
SD	City of San Diego
SF	City and County of San Francisco
SMUD	Sacramento Municipal Utility District
SSWD	South Sutter Water District
TID-MID	Turlock Irrigation District—Modesto Irrigation District
USCE	U. S. Army Corps of Engineers
USBR	U. S. Bureau of Reclamation
UWCD	United Water Conservation District
VID	Vista Irrigation District
YCFCWCD	Yolo County Flood Control and Water Conservation District
YCWA	Yuba County Water Agency

TABLE 9

STATISTICS FOR SURFACE WATER SUPPLY RESERVOIRS SHOWN ON FIGURE 21 [1]

Reservoir (Dam)	HSA	Area	Capacity	Owner [3]	Year Completed
		Acres	Acre-feet		
Clear Lake	NC	24,800	527,000	USBR	1910
Tahoe	NL	122,000	745,000 [2]	USBR	1913
Clear Lake	SB	43,000	420,000 [2]	YCFCWCD	1914
Huntington Lake	SJ	1,440	89,000	SCE	1917
Big Sage	SB	5,270	77,000	HSVID	1921
Pillsbury	NC	2,000	94,000	PGandE	1921
Hetch Hetchy	SJ	1,960	360,000	SF	1923
Henshaw	SD	6,000	204,000	VID	1923
Calaveras	SF	1,450	100,000	SF	1925
Shaver	SJ	2,180	135,000	SCE	1927
Almanor	SB	28,260	442,000 [2]	PGandE	1927
Bucks	SB	1,830	103,000	PGandE	1928
Pardee	SJ	2,130	210,000	EBMUD	1929
Salt Springs	SJ	920	139,000	PGandE	1931
Havasu (Parker)	CR	20,400	648,000	USBR	1938
Mathews	SA	2,750	182,000	MWD	1938
Crowley	SL	5,280	184,000	LADWP	1941
San Vicente	SD	1,070	90,000	SD	1943
Shasta	SB	29,500	4,552,000	USBR	1945
Millerton (Friant)	SJ	4,900	520,000	USBR	1947
Anderson	SF	980	91,000	SCVWD	1950
Isabella	TL	11,400	570,000	USCE	1953
Cachuma	CC	3,090	205,000	USBR	1953
Edison	SJ	1,890	125,000	SCE	1954
Pine Flat	TL	5,970	1,000,000	USCE	1954
Piru	LA	1,240	100,000	UWCD	1955
Folsom	SB	11,450	1,010,000	USBR	1956
Lloyd	SJ	1,760	268,000	SF	1956
Beardsley	SJ	650	98,000	OID-SSJID	1957
Nacimiento	CC	5,370	350,000	MCFCWCD	1957
Berryessa	SB	20,700	1,600,000	USBR	1957
Twitchell	CC	3,670	240,000	USBR	1958
Wishon	TL	1,000	128,000	PGandE	1958
Casitas	LA	2,720	254,000	USBR	1959
Little Grass Valley	SB	1,430	93,000	OWID	1961
Success	TL	2,400	82,000	USCE	1961
Clair Engle (Trinity)	NC	16,400	2,448,000	USBR	1962
Kaweah (Terminus)	TL	1,940	150,000	USCE	1962
Black Butte	SB	4,560	160,000	USCE	1963
Camp Far West	SB	2,680	103,000	SSWD	1963
Union Valley	SB	2,869	271,000	SMUD	1963
Camanche	SJ	7,700	431,000	EBMUD	1963
Whiskeytown	SB	3,200	241,000	USBR	1963

[1] 75,000 acre-feet or larger
[2] Above natural outlet
[3] See separate list of identification of owners
[4] Under Construction

(TABLE 9 continues on Page 66)

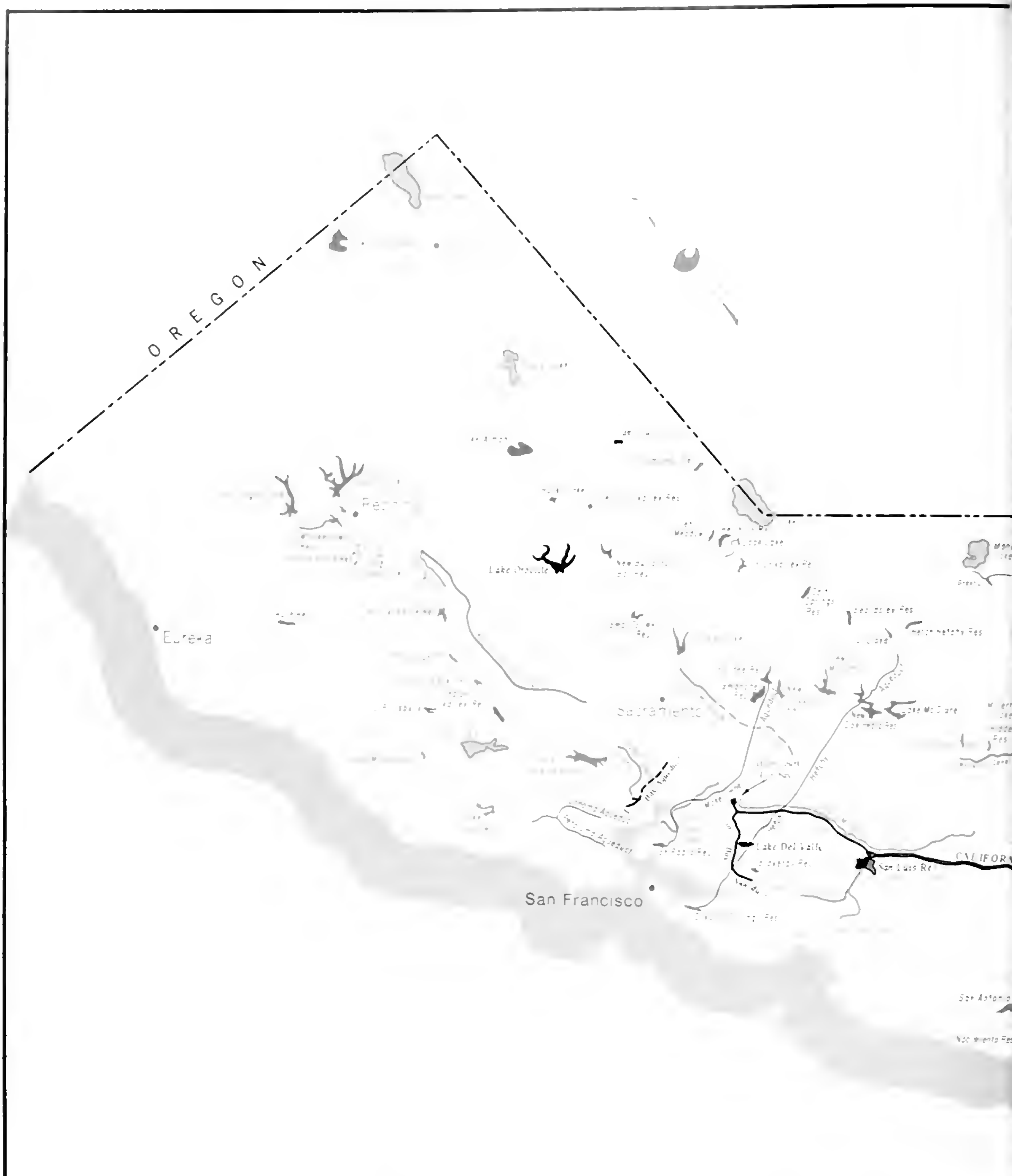
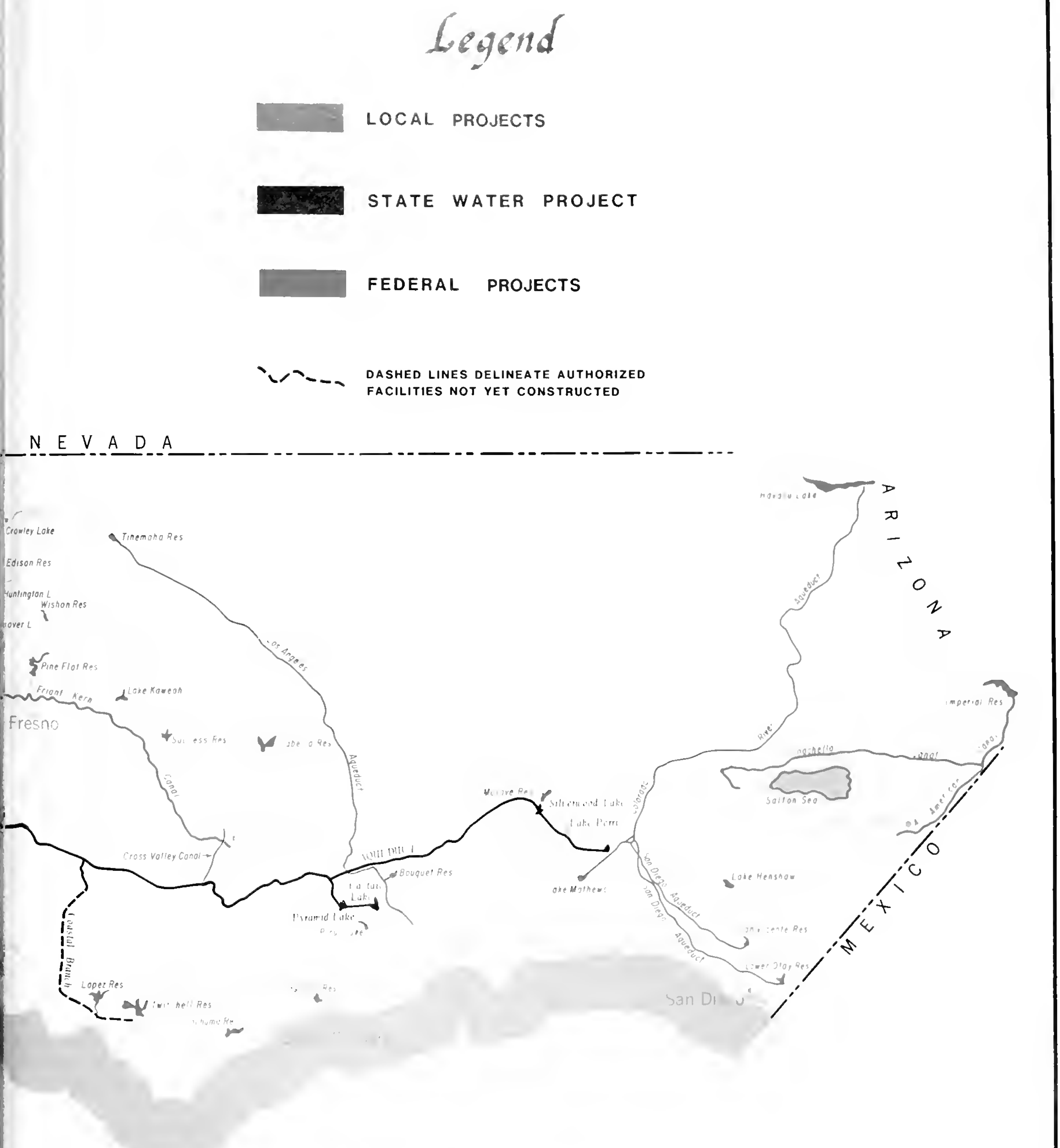


FIGURE 21. MAJOR STORAGE RESERVOIRS



AND CONVEYANCE FACILITIES

EDITION OF 1982

TABLE 9—*Continued*

STATISTICS FOR SURFACE WATER SUPPLY RESERVOIRS SHOWN ON FIGURE 21 [1]

		Area	Capacity[2]		
Reservoir (Dam)	*HSA*	*Acres*	*Acre-feet*	*Owner* [3]	*Year Completed*
Loon Lake	SB	1,450	77,000	SMUD	1963
French Meadows	SB	1,420	134,000	PCWA	1965
San Antonio	CC	5,720	348,000	MCFCWCD	1965
Hell Hole	SB	1,250	208,000	PCWA	1966
Davis (Grizzly Valley)	SB	4,000	84,000	DWR	1966
San Luis	SJ	12,700	2,039,000	DWR-USBR	1967
McClure (New Exchequer)	SJ	7,130	1,026,000	MID	1967
Oroville	SB	15,800	3,538,000	DWR	1968
New Bullards Bar	SB	4,810	970,000	YCWA	1970
Stampede	NL	3,440	225,000	USCE	1970
Mojave	SL	1,980	90,000	USCE	1971
New Don Pedro	SJ	12,960	2,030,000	TID-MID	1971
Silverwood (Cedar Springs)	SL	980	75,000	DWR	1971
Castaic	LA	2,240	324,000	DWR	1973
Perris	SA	2,320	131,000	DWR	1973
Pyramid	LA	1,360	171,000	DWR	1973
Indian Valley	SB	4,000	300,000	YCFCWCD	1976
Buchanan	SJ	1,780	150,000	USCE	1979
Hidden	SJ	1,570	90,000	USCE	1979
New Melones	SJ	12,500	2,400,000	USCE	1979
Auburn	SB	10,400	2,326,000	USBR	U.C.[4]
Sonoma (Warm Springs)	NC	3,600	381,000	USCE	U.C.
Dutch Gulch	SB	11,200	900,000	USCE	Authorized
Tehama	SB	10,200	700,000	USCE	Authorized

[1] 75,000 acre-feet or larger
[2] Above natural outlet
[3] See separate list of identification of owners
[4] Under Construction.

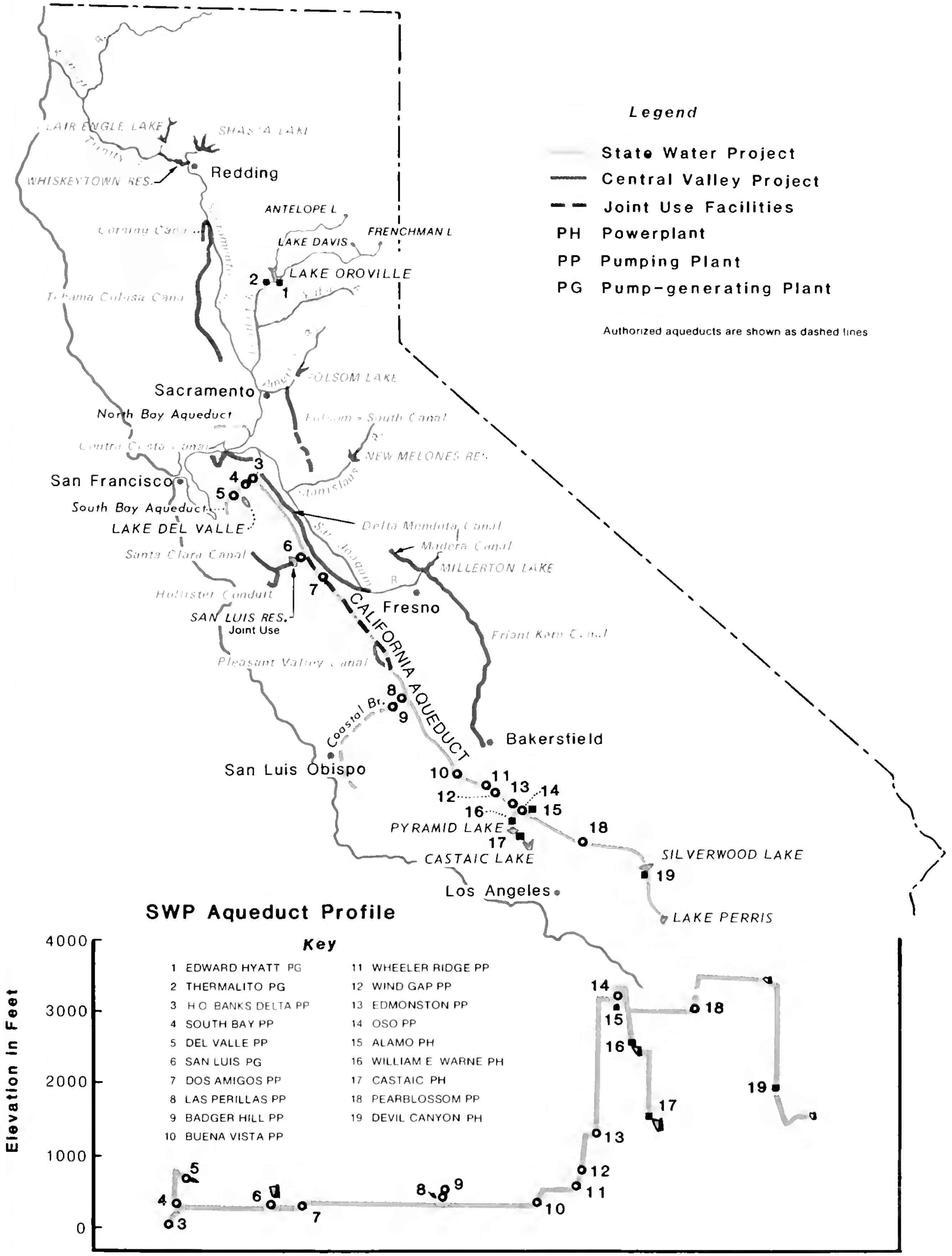
TABLE 10

STATISTICS FOR AQUEDUCTS SHOWN ON FIGURE 21 [1]

	Capacity[2]	Length		
Name	*Cubic feet per second*	*Miles*	*Owner*[3]	*Initial Year of Operation*
Los Angeles	710	244	LAPWP	1913
Mokelumne River	590	90	EBMUD	1929
Hetch Hetchy	460	152	SF	1934
All American	15,100	80	USBR	1938
Contra Costa	350	48	USBR	1940
Colorado River	1,600	242	MWD	1941
Friant-Kern	4,000	152	USBR	1944
Coachella	2,500	123	USBR	1947
San Diego No. 1	200	71	SD	1947
Delta-Mendota	4,600	116	USBR	1951
Madera	1,000	36	USBR	1952
Putah South	960	35	USBR	1957
Santa Rosa-Sonoma	62	31	SCWA	1959
San Diego No. 2	1,000	93	SD	1960
Corning	500	21	USBR	1960
Petaluma	16	26	SCWA	1961
Tehama-Colusa	2,530	113	USBR	1961[4]
South Bay	360	43	DWR	1965
North Bay	46	26	DWR	1968[5]
California	13,100	444	DWR	1972[6]
Folsom South	3,500	27	USBR	1973[7]
Cross Valley	740	20	KCWA	1975

[1] A number of major irrigation canals in the Central Valley, some as large as those shown, could not be included on the figure because of the lack of space.
[2] Initial reach only for most irrigation canals
[3] See separate list of identification of owners.
[4] Tehama and Glenn Counties.
[5] Interim facilities.
[6] To Southern California
[7] Reaches 1 and 2

Figure 22. MAJOR FEATURES OF THE STATE WATER PROJECT AND THE CENTRAL VALLEY PROJECT



The Federal Central Valley Project

The Central Valley Project (CVP) was conceived as a plan to correct the problems of natural maldistribution of water supply and needs in the great Central Valley of California. It was apparent as early as the 1920s that the natural water supply of the southern San Joaquin Valley was inadequate to meet the needs of this fertile area.

Planning and Implementation

In 1921, the State Legislature authorized the State's water officials, then in the Department of Public Works, to conduct a statewide water resources investigation. The Department made several reports to the State Legislature during the next 10 years, and in 1931 submitted a report on the "State Water Plan." The plan provided for a transfer of surplus water from the northern to the southern portion of the Central Valley and served as the basis for the present federal Central Valley Project.

In 1933, the Legislature passed the State Central Valley Project Act to implement the CVP, the initial feature of the State Water Plan. In addition to water storage and conveyance features, the act included a provision for public construction of both generating plants and transmission lines. As a result of a referendum campaign, the proposal was then placed before the voters of the State in a special election held in December 1933, and the act authorizing the CVP obtained statewide approval by a narrow majority. State funds to begin construction could not be obtained, however, because the nationwide economic depression made the revenue bonds unmarketable. Consequently, arrangements were made for federal authorization and financing, first administratively, and later under the Rivers and Harbor Act of 1937. Congress authorized the project for construction by the U.S. Bureau of Reclamation (USBR) to improve navigation, regulate the flows of the San Joaquin and Sacramento Rivers, control floods, store water, reclaim arid and semiarid lands, and generate electric energy.

The authorizing act declared that the dams and reservoirs "shall be used first for river regulation, navigation and flood control; second for irrigation and domestic uses; and third for power." Salinity control in the Delta was not specifically listed as a project purpose; development of facilities and water supplies for recreation, fish, and wildlife have been included in subsequent reauthorizations of the CVP.

Principal Features and Operation

USBR operates the CVP principally to transport water from the Sacramento, Trinity, American, and San Joaquin River Basins to the water-deficient areas of the Sacramento and San Joaquin Valleys. The key water supply feature is Shasta Reservoir on the Sacramento River. Water stored here is first used to generate power—as at most CVP reservoirs—and then flows south in the natural channel of the Sacramento River toward the Delta. Diversions from the Trinity Division (Clair Engle Lake) also flow in the Sacramento River to the Delta. Water stored by the Friant Division is transported to the Tulare Lake Basin by the Friant-Kern Canal and to the San Joaquin Basin by the Madera Canal.

At Red Bluff, a diversion dam diverts water from the Sacramento River to the Corning Canal and the Tehama-Colusa Canal to irrigate lands in Tehama, Glenn, and Colusa Counties, and northern Yolo County. In addition, numerous CVP water users divert their supply directly from the Sacramento River.

American River water is stored in Folsom Lake for use in the Folsom-South service area and for release to the Delta. Below Folsom Dam, Nimbus Dam acts as an afterbay, reregulating the releases for power, and directs water into the Folsom-South Canal to provide cooling water for Rancho Seco power plant. Completion of the canal to provide water to San Joaquin County has been deferred, pending resolution of problems concerning Auburn Dam and the lower American River.

South of Sacramento, the Delta Cross Channel facilitates the flow of water from the Sacramento River across the Delta to the Rock Slough Intake of the Contra Costa Canal and to the export pumps near Tracy, while improving the quality of irrigation supplies in the central Delta.

From Rock Slough in the southern Delta, the CVP supplies water to the Contra Costa Canal, the first unit of the CVP to become operational (1940). This canal extends west 48 miles to the vicinity of Martinez, providing water for municipal, industrial, and irrigation uses.

The Tracy Pumping Plant lifts as much as 4,600 cubic feet per second 197 feet into the Delta-Mendota Canal, which delivers water to the lower San Joaquin Valley as far as 117 miles south, terminating at the San Joaquin River at the Mendota Pool. There it replaces a portion of the natural flows of the San Joaquin River that are stored by Friant Dam (Millerton Lake) in the Sierra Nevada foothills northeast of Fresno. Water from Millerton Lake is distributed north and south, respectively, through the Madera and Friant-Kern Canals.

About 60 miles south of the Delta, between the Delta and the Mendota Pool, is the federal-State, joint-use San Luis Dam and Reservoir, an offstream storage facility of the CVP and the SWP. Water diverted from the Delta by both the Delta-Mendota Canal (CVP) and the California Aqueduct (SWP) is pumped into San Luis Reservoir during the winter and early spring for release to service areas during the summer and fall.

The most recent addition to the CVP (1979) is New Melones Dam and Reservoir on the Stanislaus River. Controversy surrounding this project has resulted in two statewide initiatives, Proposition 17 in 1974 and Proposition 13 in 1982, along with several legal actions. The project was constructed by the Corps of Engineers and has been turned over to USBR for operation.

New Melones Reservoir provides additional flood control protection and releases for downstream fishery purposes, water quality control, downstream water rights, power generation, recreation, and a water supply for irrigation and municipal and industrial uses. In March 1983, the State Water Resources Control Board lifted the restrictions it had previously placed on the filling of New Melones Reservoir, permitting the full storage of water for power generation and consumptive use.

The Bureau of Reclamation is well advanced in pursuing water service contracts for interim and firm water supplies with the Tuolumne Regional Water District, the Central San Joaquin Water Conservation District, and the Stockton-East Water District. It is expected that the water serv-

ice contracts will have been approved and executed in fall of 1983.

The San Felipe Division of the CVP is presently under construction. By pumped diversions from San Luis Reservoir via the Pacheco tunnel, service will be provided to parts of the Santa Clara Valley and Santa Clara and San Benito Counties, and possibly later to Santa Cruz and Monterey Counties.

Social, Environmental, and Economic Impacts

The development and growth of the Central Valley Project has stimulated economic and social growth throughout California's Central Valley—especially in the San Joaquin Valley. Communities have developed in some of the new farming areas. Several San Joaquin Valley counties are among the top counties in the nation in value of farm products—due to farming operations made possible by CVP and other water supplies.

In 1982, nearly 2.7 million acres of farmland in the Central Valley received irrigation water service from the CVP. This service contributed to the production of approximately $3 billion in gross crop receipts at the farm, which in turn stimulated an estimated $3–$4 billion in additional economic activity elsewhere in California and the nation.

Californians spend millions of "recreation days" each year enjoying the boating, fishing, swimming, picnicking, and other outdoor recreation opportunities afforded by CVP facilities. While many of these environmental benefits represent improvement over previous opportunities, not all CVP environmental impacts have been beneficial. Effects unrecognized at the time of planning and construction have harmed fish and wildlife. Red Bluff Diversion Dam has been implicated in a variety of negative impacts on anadromous fish in the upper Sacramento River. The Tehama-Colusa Canal Fish Facilties were constructed as mitigation for the dam. The fish facilities slightly exceed the original mitigation requirements, but there are additional problems that were not anticipated when the dam was built. Presently, USBR is funding two separate programs to develop and implement solutions to the fish problems at the dam and fish facilities. The unfenced, concrete-lined Tehama-Colusa Canal is also a hazard to wildlife, claiming as many as 300 deer per year by drowning as they attempt to cross the canal. Friant Dam was completed in June 1944, without mitigation provisions for salmon. Since then, salmon runs on the San Joaquin River have been depressed.

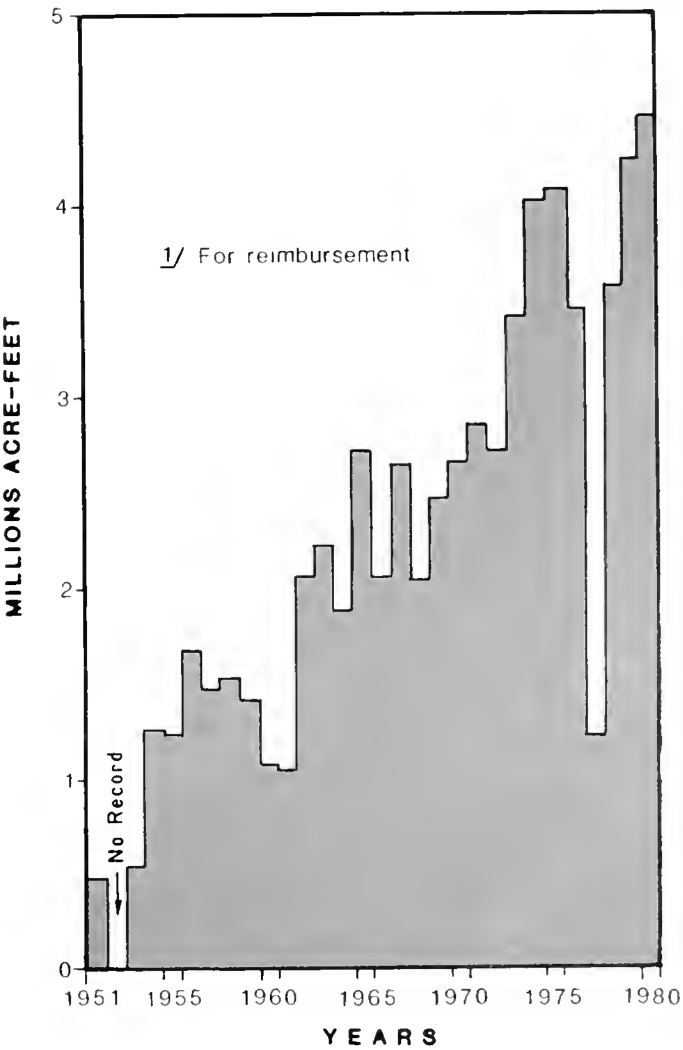
Trinity Dam blocks anadromous salmon and steelhead from reaching the upper part of the Trinity River. The Trinity Hatchery was built to offset the loss of habitat upstream from the dam. A minimum flow release was agreed upon, but the release proved inadequate to prevent degradation of the downstream habitat. USBR was the lead agency for a multi-agency investigation of fish problems in the Trinity River, and a multi-year study of a variety of solutions, including increased streamflow releases, has been proposed.

Financing and Repayment

Financing of the CVP facilities has its roots in federal reclamation laws and policies. Under existing laws and current policies, capital and operation and maintenance costs are allocated to and repaid by those who benefit from the project. Costs allocated to flood control and navigation are considered to benefit the nation and are repaid from the federal treasury. Costs allocated to recreation, fish, and wildlife enhancement are borne by both federal and nonfederal interests. Costs allocated to the municipal and industrial water supply and commercial power purposes are repaid with interest by the municipal and industrial and power contractors. Costs allocated to irrigation are repaid without interest by the CVP irrigation contractors, with provisions for financial assistance from other water and power beneficiaries whenever the cost of irrigation water service exceeds the irrigator's repayment ability.

CVP water and power users are scheduled to repay about 85 percent of the authorized project costs, inasmuch as the water and power customers will realize the largest portion of the project benefits. The State of California will contribute an amount equal to about 3 percent of the authorized capital cost as payment of its share of the cost of the joint federal-State San Luis facilities. Local entities will repay an amount equal to less than 1 percent of the total project cost as their share of local recreation, fish, and wildlife enhancement. The remaining 11 percent will be repaid by the federal government as its contribution toward flood control, navigation, and nonreimbursable recreation, fish, and wildlife.

Figure 23a. CVP DELIVERIES 1/ FOR THE PERIOD 1951–1980



CENTRAL VALLEY PROJECT FEATURES

Reservoir (Dam)	Capacity Acre-feet	Surface Area Acres	Purpose[6]	Year Completed
Shasta Lake	4,552,000	29,740	W, P, F, R	1945
Clair Engle Lake (Trinity)	2,448,000	16,535	W, P, R	1962
Lewiston Lake	14,600	800	W, P	1963
Whiskeytown Lake	241,000	3,220	W, P, R	1963
Spring Creek Debris	5,900	87	D	1963
Keswick	23,800	640	P, S	1950
Red Bluff Diversion	3,900	530	W	1964
Black Butte[1]	160,000	4,560	W, F, R	1963
Jenkinson Lake (Sly Park)[2]	41,000	650	W, R	1955
Folsom Lake	1,010,000	11,450	W, P, F, R	1956
Lake Natoma (Nimbus)	8,800	540	P, S	1955
Contra Loma	2,100	81	R, S	1967
San Luis[3]	2,038,800	12,700	S, R, P	1967
O'Neill (San Luis Forebay)[3]	56,400	2,250	S	1967
Los Banos[3]	34,600	470	D	1965
Little Panoche[3]	5,600	188	D	1966
Millerton Lake (Friant)	520,500	4,900	W, P, F, R	1942
New Melones	2,400,000	12,500	W, P, F, R	1979
Sugar Pine	7,000	142	W, R	1982

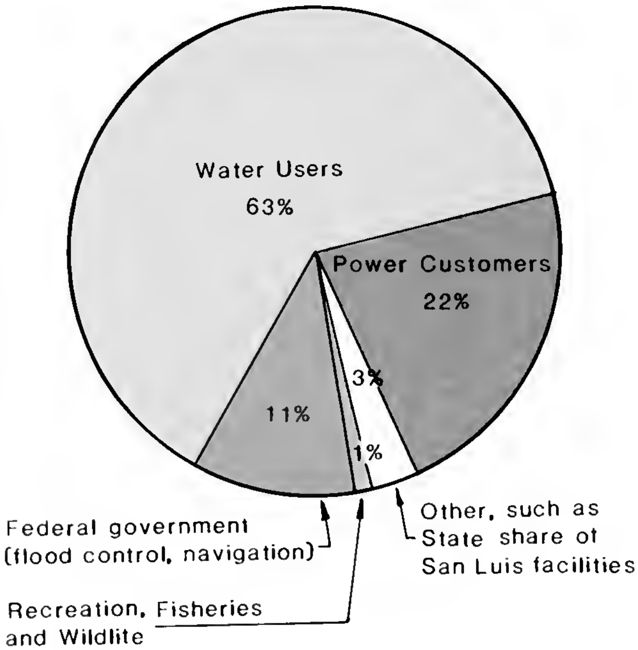
Aqueduct	Capacity Cubic feet per second	Length Miles	Year Completed
Corning	500	21	1959
Folsom South	3,500	27	1973[4]
Contra Costa[5]	350	48	1948
Delta-Mendota	4,600	116	1951
San Luis[3]	13,100	101	1967
Madera	1,000	36	1952
Friant-Kern	4,000	151	1944
Tehama-Colusa	2,530	113	1961

[1] Operated by the Corps of Engineers
[2] Operated by El Dorado Irrigation District
[3] Joint use with State Water Project, operated by State of California.
[4] Only first 27 miles complete out of a total of about 68 miles
[5] Operated by Contra Costa County Water District
[6] W—Water supply, P—Power, F—Flood control, R—Recreation, D—Debris control, S—Reregulatory storage.

Year	Area Irrigated Acres
1968	1,464,100
1969	1,530,200
1970	1,542,000
1971	1,624,200
1972	1,733,400
1973	1,933,900
1974	2,040,500
1975	1,932,700
1976	1,958,100
1977	1,814,100

Source U.S. Department of the Interior, Water and Power Resources Service, *Project Data*, 1981

Figure 23b. SOURCES OF REPAYMENT OF PROJECT COSTS TO END OF REPAYMENT PERIOD (2050)



The California State Water Project *

Planning for the State Water Project (SWP), originally called the Feather River Project, began after World War II. During the latter part of the 1940s, the State Division of Water Resources conducted two programs. One concentrated on collecting basic data and developing a statewide water plan—the California Water Plan. The other considered a specific project as the initial State-constructed portion of the plan. The first complete report on the project, published in 1951, proposed a multiple-purpose dam and reservoir on the Feather River near Oroville, with a power plant, an afterbay dam and power plant, a Delta cross channel, an electric power transmission system, an aqueduct to transport water from the Delta to Santa Clara and Alameda Counties, and an aqueduct to transport water from the Delta to the San Joaquin Valley and Southern California.

Some of the factors that influenced the State to become directly involved in water development were:

- Rapid population growth in Southern California was expected to exceed the capacity of available water supplies, and additional water could be obtained only in Northern California.
- Federal water development agencies were primarily concerned with providing irrigation supplies (USBR, under the federal Reclamation Act) or flood control (U.S. Army Corps of Engineers). They were not authorized to construct major inter-basin water supply projects to meet municipal and industrial needs. Therefore, the State was the more appropriate agency.
- A number of State and local water agencies were dissatisfied with federal policies affecting construction and operation of the federal CVP, the project originally conceived and planned by the State. It was believed that the irrigation and power policies of the CVP should be directed by the State so that the project could be more responsive to California's social and economic issues.
- San Joaquin Valley farmers believed the 160-acre limitation on use of CVP water was inappropriate because the water was being used as a supplement by large farms that were already established through the use of ground water and local surface water supplies.
- Private utilities wanted to prevent further expansion of low-cost, subsidized public power generation and transmission.

The project was authorized by the Legislature in 1951 under the State Central Valley Project Act. It was designated "The Feather River and Sacramento-San Joaquin Delta Diversion Project." Operating under authorization of the State Central Valley Project Act of 1933, the Water Project Authority, through the Division of Water Resources, continued investigations, surveys, and studies, including the preparation of plans and specifications for construction of the authorized works.

In 1955, after approval of its plans by the Water Project Authority, the Division submitted another report to the Legislature on the proposed project. This report stated that the project had engineering and financial feasibility and recommended that the Legislature appropriate funds to start construction. The report also recommended adding San Luis Reservoir on the west side of the San Joaquin Valley for offstream storage of Delta surplus flows.

To further the development of the State's water resources program, the Legislature, in 1956, established the Department of Water Resources, and nearly all the functions and authorities of the Water Project Authority, the State Water Resources Board, and the Division of Water Resources of the Department of Public Works were transferred to the new department. Appropriation of water and the determination of water rights were vested in a new State Water Rights Board (now the State Water Resources Control Board).

Construction funds for the SWP were first made available to the Department in 1957, when the Legislature, reacting to the widespread flooding that occurred during December 1955 and January and February, 1956, appropriated over $25 million in State tidelands oil revenues to begin highway and railroad relocation around the Oroville reservoir site. Year-to-year funds were appropriated through 1960 to permit continuation of the Oroville relocations and to permit the start of construction of the South Bay and California Aqueducts in 1959.

An assured source of project funds was established when the Legislature enacted the California Water Resources Development Bond Act (Burns-Porter Act) in 1959 and California voters approved it in November 1960 by a margin of 173,944 out of a total of 5.8 million votes cast. Popular support in Southern California delivered this narrow victory. Butte County, site of the proposed Oroville Dam, and Yuba County were the only two counties north of Fresno to vote for the bond act. These results represented a reversal of the votes cast in the 1933 referendum on the State CVP Act when Southern California voted against the issue and Northern California supported it.

The 1959 bond act authorized issuance of $1.75 billion in general obligation bonds, backed by the State's full faith and credit, and appropriated all moneys in and accruals to the California Water Fund for construction of the SWP.

The Burns-Porter Act authorized certain facilities, including:

- A multiple-purpose dam and reservoir at Oroville, and five upstream reservoirs in Plumas County.
- An aqueduct system, including North Bay, South Bay, San Joaquin Valley-Southern California, and coastal aqueducts; and an offstream storage reservoir near Los Banos.
- Facilities in the Sacramento-San Joaquin Delta for water conservation, water supply in the Delta, transfer of water across the Delta, flood and salinity control, and related functions.
- Additional unspecified facilities in the Sacramento and certain north coastal watersheds for local needs and to augment water supplies in the Delta, as necessary.
- Local projects provided for under the Davis-Grunsky Act for which State loans and grants are authorized.

The State entered into contracts with 31 water agencies ** to deliver an ultimate 4.23 million acre-feet of water

* For a more complete discussion, see: Department of Water Resources, *California State Water Project*, Bulletin 200, Vol. I, "History, Planning, and Early Progress," November 1974.

** Because two contracting agencies have since merged, there are now 30 water service contractors. The total SWP water service obligations are unchanged.

annually to service areas in northern, central, and southern parts of California. The facilities now constructed can deliver about 2.3 million acre-feet of water per year on a dependable basis and up to 3 million acre-feet in a wet year. Additional facilities will be required to meet full contract entitlements and to compensate for future depletion of Delta surplus flows. Present excess supplies are sold as "surplus water for irrigation and ground water recharge."

Principal Features and Operation

The initial facilities of the SWP are shown on the accompanying map. The project begins with three small reservoirs on Feather River tributaries in Plumas County—Lake Davis and Frenchman and Antelope Lakes—which are devoted primarily to recreation. Farther downstream, water released from the main storage facility, Lake Oroville, flows through power generating facilities, thence down the Feather River and the Sacramento River, and into the network of channels in the Sacramento-San Joaquin Delta.

The North Bay Aqueduct, scheduled for completion before 1990, will deliver water to Napa and Solano Counties. Interim facilities serve Napa County with water from the Solano Project of the U.S. Bureau of Reclamation.

At the southern edge of the Delta are the Clifton Court Forebay, the John E. Skinner Fish Protective Facilities, and the Harvey O. Banks Delta Pumping Plant.

At the pumping plant, water is lifted 244 feet into the California Aqueduct.[5] The South Bay Aqueduct branches at this point and delivers water as far west as San Jose. The California Aqueduct conveys water south to the San Joaquin Valley and Southern California. Surplus winter and spring flows from the Delta are stored in San Luis Reservoir, a joint federal-State facility, for use later in the year. An aqueduct planned to serve areas in San Luis Obispo and Santa Barbara Counties has been delayed and the area's entitlement was reduced as the result of action by Santa Barbara County.

Environmental Impacts

Operation of the SWP has both a positive and a negative effect on the environment. Fish species characteristic of the Bay-Delta system have declined because of the transfer of SWP and CVP water across the Delta. These diversions have resulted in reverse flows in some waterways that interfere with migrating salmon. Loss of fish fry and food organisms occurs in the Harvey O. Banks Delta Pumping Plant.

On the other hand, salmon runs in the Feather River are greater now than before Oroville Dam was built. Releases are controlled to produce better water temperature conditions and improved habitat, especially during subnormal periods of runoff. A substantial striped bass fishery has become established in the California Aqueduct and in Southern California reservoirs, providing fishing opportunities where few existed before. Streamflow releases from Antelope Reservoir have improved the fishery potential in many miles of Last Chance Creek.

[5] The aqueduct was renamed the Governor Edmund G. Brown California Aqueduct in December 1982.

Economic Impacts

The SWP not only has had an immediate economic impact upon the surrounding region during construction, but also has long-term effects upon regional and State economies.

In some areas, the impact has substantially affected the entire growth pattern and economy of a region. For example, within Kern County (the primary county in the San Joaquin service area), about 90 percent of the SWP deliveries are used for agriculture. SWP supplies comprised about 25 percent of the county's overall water supplies in 1980. In 1980, Kern was the State's third leading agricultural county, with gross farm receipts of more than $1.27 billion. Cotton, the leading crop, accounts for almost half the county's harvested acreage. Grapes rank second in agricultural value, followed by almonds.

In addition to the direct value of crops, economic activity is also stimulated in those secondary industries supplying the agricultural producers with products and services, as well as in the food processing industries.

Water supplies can also have an economic impact upon urban areas, although the effect is much more complex and more difficult to quantify than for agricultural regions. SWP deliveries to the Southern California, Central Coast, South Bay, and North Bay service areas are necessary for economic growth. However, other factors—such as employment opportunities, resource availability, climate, housing markets, community lifestyles, and local growth management policies—also influence growth. The relative significance of water compared to these other factors is difficult to assess.

Financing and Repayment

Capital cost financing for the SWP is obtained from several sources. Major sources are general obligation bond proceeds, the California Water Fund (tideland oil revenues), revenue bond proceeds, and miscellaneous receipts.

The basic concept for repayment for the State Water Project (SWP) is that the costs are to be allocated to and repaid by those who benefit from the project. Major beneficiaries of the SWP are the now 30 agencies that have long-term water service contracts with the State. Under the terms of their contracts, these agencies will repay all reimbursable costs of the project that are allocated to water supply (about 96 percent of total project costs, under current allocations). Those who receive the direct benefits repay the entire principal and interest cost of the general obligation bond issue, plus all other construction and operation costs of the project.

The water users—the major beneficiaries—are paying the largest part of the costs. State funds repay cost of the broad benefits for all Californians—the costs allocated to recreation and fish and wildlife enhancement (about 3 percent of costs). Costs of providing flood control at Lake Oroville and Lake Del Valle (about 1 percent of the costs) are not repaid (nonreimbursable) by SWP contractors; they are repaid by the federal government.

Figure 24a. SWP DELIVERIES 1/ FOR THE PERIOD 1962-1981

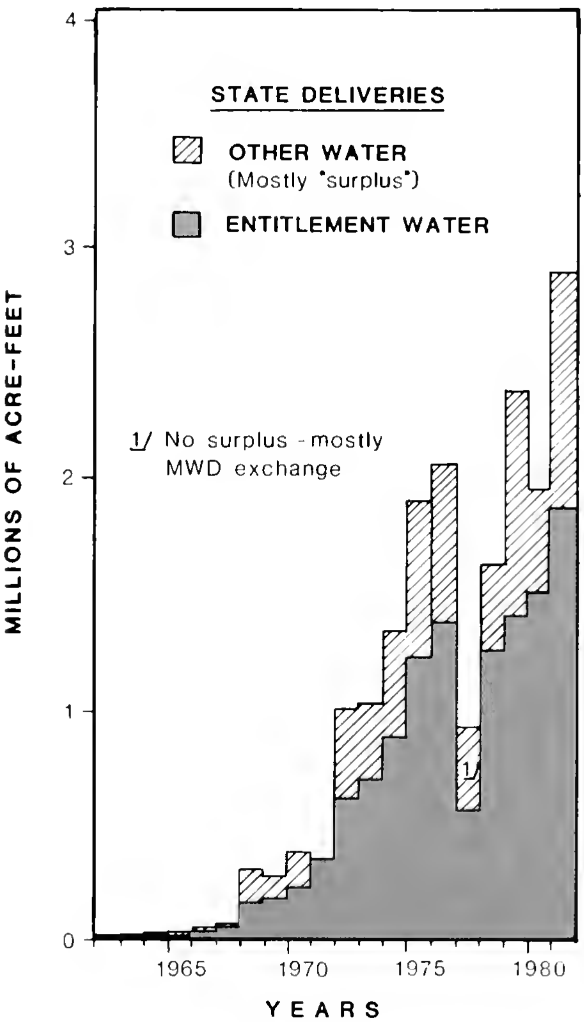
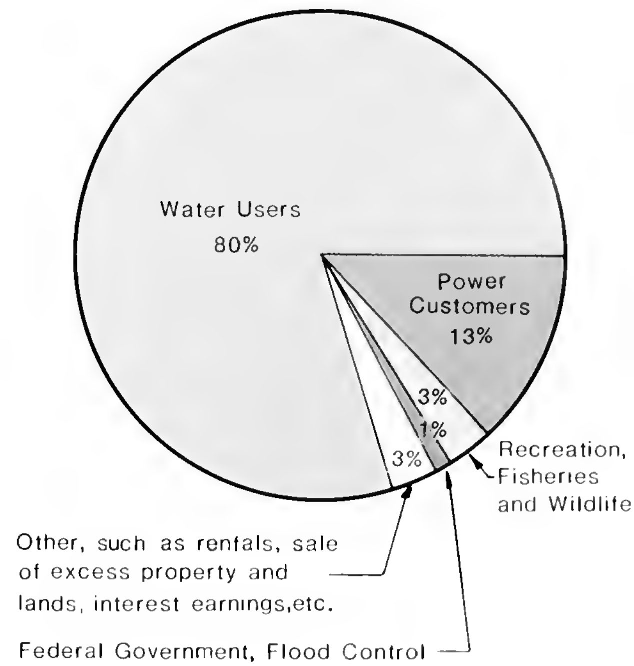


Figure 24b. SOURCES OF REPAYMENT OF PROJECT COSTS TO END OF REPAYMENT PERIOD (2035)



STATE WATER PROJECT FEATURES

Reservoir (Dam)	Capacity	Surface Area	Purpose[1]	First Year of Operation
	Acre-feet	Acres		
Frenchman Lake	55,500	1,580	R, W	1961
Antelope Lake	22,600	931	R	1964
Lake Davis	84,400	4,026	R, W	1966
Lake Oroville	3,537,600	15,805	W, P, F, R	1968
Thermalito Diversion Pool	13,300	323	P	1967
Thermalito Forebay	11,800	630	P, R	1967
Thermalito Afterbay	57,000	4 302	S, R	1967
Clifton Court Forebay	28,700	2 109	S	1969
Bethany	4,800	161	S, R	1961
Lake Del Valle	77,100	1,060	S, R	1968
San Luis[2]	2,038,800	12,700	S, R, P	1967
O'Neill Forebay	56,400	2,700	S	1967
Los Banos	34,600	623	D	1965
Little Panoche	13,200	354	D	1966
Silverwood Lake	75,000	976	S, R	1971
Lake Perris	131,500	2,318	S, R	1973
Quail Lake	5,000	223	S	
Pyramid Lake	171,200	1,297	S, P	1973
Elderberry Forebay	28,200	460	S, R	1974
Castaic Lake	323,700	2,235	S, P, R, W	1973
Castaic Lagoon	5,700	196	R	1972

Aqueduct	Capacity	Length
	Cubic feet per second	Miles
North Bay	46	25[3]
South Bay	360	43
California (main line)	13,100	444
California (branches)		
West Branch	3,130	32
Coastal Branch	450	96[3]

[1] W—Water supply, F—Flood control, D—Debris control, P—Power, R—Recreation, S—Reregulatory storage.
[2] Joint use with Central Valley Project, operated by State of California
[3] Total of completed and proposed length.

Recent Surface Water Projects

Several major water storage and distribution facilities have been completed by federal, State, and local agencies since publication of Bulletin 160-74 in 1974. In addition, another major reservoir project, Warm Springs Dam, is nearing completion, and construction has been suspended on another (Auburn Dam), pending redesign and reauthorization.

Local Projects. Projects completed by local agencies were Indian Valley Dam on North Fork Cache Creek in Lake County, Soulajule Dam on a tributary to Walker Creek in Marin County, and the Cross Valley Canal in Kern County.

The Indian Valley project was constructed by Yolo County Flood Control and Water Conservation District to provide supplemental water supplies to eastern Yolo County, an area of ground water overdraft. It will augment the district's surface supplies available from Clear Lake.

Soulajule Dam was constructed by the Marin Municipal Water District to provide about 5,000 acre-feet more water per year to the district's service area in eastern Marin County. Water is pumped from the 10,560-acre-foot capacity reservoir through a pipeline to Nicasio Reservoir (see Plate 1 for location). From there it enters the district's delivery system.

The Cross Valley Canal was constructed to facilitate exchanges of Central Valley Project water to nine agencies in three counties in the Tulare Lake HSA. The water is made available to the agencies through an exchange agreement between the agencies and the Arvin-Edison Water Storage District (WSD). CVP water carried in the Cross Valley Canal is pumped from the Delta and conveyed to the head of the canal near Tupman via the California Aqueduct. The water is then conveyed through the canal to Arvin-Edison WSD. An equal amount of water is thereby made available to CVP's Cross Valley Canal contractors from Arvin-Edison WSD's Friant-Kern Canal contractual entitlement.

Federal Projects. The U.S. Army Corps of Engineers completed Hidden Dam on the Fresno River and Buchanan Dam on the Chowchilla River and is nearing completion of Warm Springs Dam on Dry Creek, a tributary of the Russian River. All three reservoirs provide flood control, water supply, recreation areas for public use, and habitat for fish and wildlife. The Hidden and Buchanan projects have been incorporated into the CVP. The Corps of Engineers also completed New Melones Dam on the Stanislaus River in 1979 and has turned it over to the U.S. Bureau of Reclamation for operation as part of the CVP. USBR is currently negotiating for the sale of project yield to water users in San Joaquin, Stanislaus, Tuolumne, and Calaveras Counties, which make up the designated service area. This project has been involved in considerable controversy.

USBR completed construction of Sugar Pine Dam and pipeline, a feature of the Auburn-Folsom South

Water pumped from natural underground reserves is a vital source for irrigated agriculture.

Unit of the CVP. The project (shown on Plate 1) will provide supplemental water supplies for the service area of the Foresthill Divide Public Utility District.

Ground Water

Hydrologically, the ground water supply consists of the average annual natural and artificial recharge, deep percolation of excess applied surface water, and extraction from long-term ground water storage (overdraft).

Present Knowledge of Ground Water Conditions. Current statistics on ground water recharge, storage capacity, empty storage capacity, and water in storage are not readily available for the entire State because there is no statewide requirement for reporting ground water extraction, use, or artificial recharge. The Department of Water Resources makes detailed studies of a few of California's 394 ground water basins each year, and determines current yield, water-in-storage, and storage capacity. In 1975 the Department published *California's Ground Water* (Bulletin 118), which presented the information available at that time. It was not complete for all basins, however, and some information was considerably out of date.

As should be expected, the most information exists for the most heavily used basins. There is substantial knowledge of many of the developed Southern California basins and most of the San Joaquin Valley basins. Moderate information is available on other basins in the South Coastal region, the western areas of the Colorado River and South Lahontan HSAs, and Central Valley areas near the Delta. Limited information is available on ground water basins in the Sacramento Valley and the Coastal Range valleys, the northeast basins, and some desert basins. Only superficial information is available on the remaining basins, predominantly situated in desert areas. Moreover, little is understood of the potential yield in fractured-rock ground water areas, which are an important source of water for some agricultural and residential development in the Sierra Nevada foothills and other foothill and mountain areas. Fresh ground water is known or suspected to exist offshore in more than 10 coastal areas, but specific data are lacking, except for Monterey Bay and the area off the coast of Ventura County. General information on water in storage and total storage capacity by major regions of the State is summarized in Table 11.

TABLE 11
GROUND WATER STORAGE CAPACITY BY REGION
1980
(In 1,000s of acre-feet)

Region	*Water in Storage*	*Empty Storage Capacity*	*Total Storage Capacity*
North Coast (North Coast and San Francisco Bay HSAs)	4,000	1,000	5,000
Central Coast HSA	18,000	2,000	20,000
South Coast (Los Angeles, Santa Ana, and San Diego HSAs)	95,000	5,000	100,000
Central Valley (Sacramento, San Joaquin, and Tulare Lake HSAs)	540,000	38,000	578,000
Lahontan (North Lahontan and South Lahontan HSAs)	100,000	57,000	157,000
Colorado River HSA	100,000	58,000	158,000
TOTAL	857,000	161,000	1,018,000

Dependable Ground Water Supply and Overdraft. Ground water supply is presented in this report by HSA, rather than by specific ground water basin. Dependable ground water supply is defined as average natural recharge, together with intentional artificial recharge with local surface water. Deep percolation of excess applied water, intentional recharge with imported water supplies, and seepage from water conveyance systems are also components of ground water recharge. However, they are not counted as part of dependable ground water supply because doing so would, in effect, constitute double counting and would overstate the basic supply available to meet net water use.

Overdraft of a ground water basin occurs when the amount of water pumped exceeds the amount of recharge water from all sources over a long period of time. In *Ground Water Basins in California* (Bulletin 118-80, January 1980), the Department of Water Resources defines a basin as subject to critical conditions of overdraft when continuation of present water management practices would probably result in significant overdraft-related environmental, social, or economic impacts. The Department's report identified 40 basins in California known to be in overdraft, with 11 of them in "critical" conditions of overdraft (Figure 25). Basins not indicated on the figure may also be in overdraft, but they have not been studied.

The hydrologic balances by HSA appearing at the end of this chapter reveal the present status of the ground water supply; that is, those HSAs in which overdraft occurs and those in which pumping and recharge approach a balance. Such balances, as summarized, may be misleading where more than one ground water basin is included in one HSA or where more than one HSA overlies a single ground water basin. For example, in an HSA, one ground water basin may be in hydrologic balance, while another may be in a condition of overdraft.

Ground Water Levels and Pumping Costs. The water level in basins north of the city of Sacramento is less than 100 feet below the surface in all but isolated areas in late summer. Coastal basins general-

ly have relatively high water levels, but sea-water intrusion can occur where inland ground water levels have been drawn below sea level, such as in Ventura County. Basins in Southern California generally have water levels less than 200 feet below ground surface.

Water levels have been declining in overdraft areas for a long time, but this decline is not economically significant in most areas, although in parts of the San Joaquin Valley, the resultant subsidence has damaged wells and conveyance systems, and water may have to be lifted as much as 800 feet in some wells. In most of the valley, where ground water is used, pumping lifts are less than 400 feet, with much of the area having lifts of less than 200 feet.

The 1980 cost of pumping ground water in California, including capital cost and maintenance, ranges generally from about $10.00 per acre-foot in shallow water depth areas to about $40.00 per acre-foot in areas with lifts of 400 feet, such as portions of Kern County. Energy use varies with the size and condition of the pump and motor and the height of the pumping lift—all factors that affect the cost of pumped ground water.

Conjunctive Use and Ground Water Management

Ground water management develops locally in stages. Early indications of falling water levels are usually followed by some artificial recharge of the ground water basin with excess surface water in wet years or wet periods of the year. The next step, conjunctive use, is taken when water levels continue to drop. This procedure involves artificial recharge in wet times and installation of joint delivery systems so that surface water can be used directly when available, and ground water can be pumped when surface water is not available. The co-delivery systems can function on individual farms or as part of a water agency's facilities. Much of the east side of the San Joaquin Valley operates in this manner.

Coordination of surface storage with conjunctive use is one step closer to full ground water management. Storm runoff is captured in surface water reservoirs and released to ground water at an appropriate recharge rate. Empty space is retained in the reservoirs to capture the runoff from the next storm. Local surface water is managed this way in the Santa Clara Valley south of San Francisco Bay.

Ground water management, as defined in Bulletin 118-80, includes planned use of the ground water basin yield, storage space, transmission capability, and water in storage. It includes:

- Protection of natural recharge and use of artificial recharge.
- Planned variation in amount and location of pumping over time.
- Use of ground water storage conjunctively with surface water from local and imported sources.
- Protection and planned maintenance of ground water quality.

The term *planned*, appearing throughout the ground water management definition, implies a local commitment to some regulation of pumping and zoning of recharge areas. This full ground water management concept is approached by the Santa Clara Valley Water District in Santa Clara County and the Orange County Water District without adjudication, and by most adjudicated basins. The unadjudicated basins rely on a combination of imported water and pump taxes to regulate pumping.

GROUND WATER STORAGE DEFINITIONS

Five different kinds of ground water storage are recognized: total storage capacity, water in storage, available storage capacity, regulatory storage capacity, and usable storage capacity.

Total storage capacity of a ground water basin is the total volume of space between soil particles that could be occupied by ground water. It is computed as the product of the average depth of the basin material, the area of the basin, and the average specific yield* of basin materials, usually expressed in acre-feet. Some limit of upper and lower elevation is usually given to define total storage capacity. A reasonable upper limit is 20 to 50 feet below the ground surface.

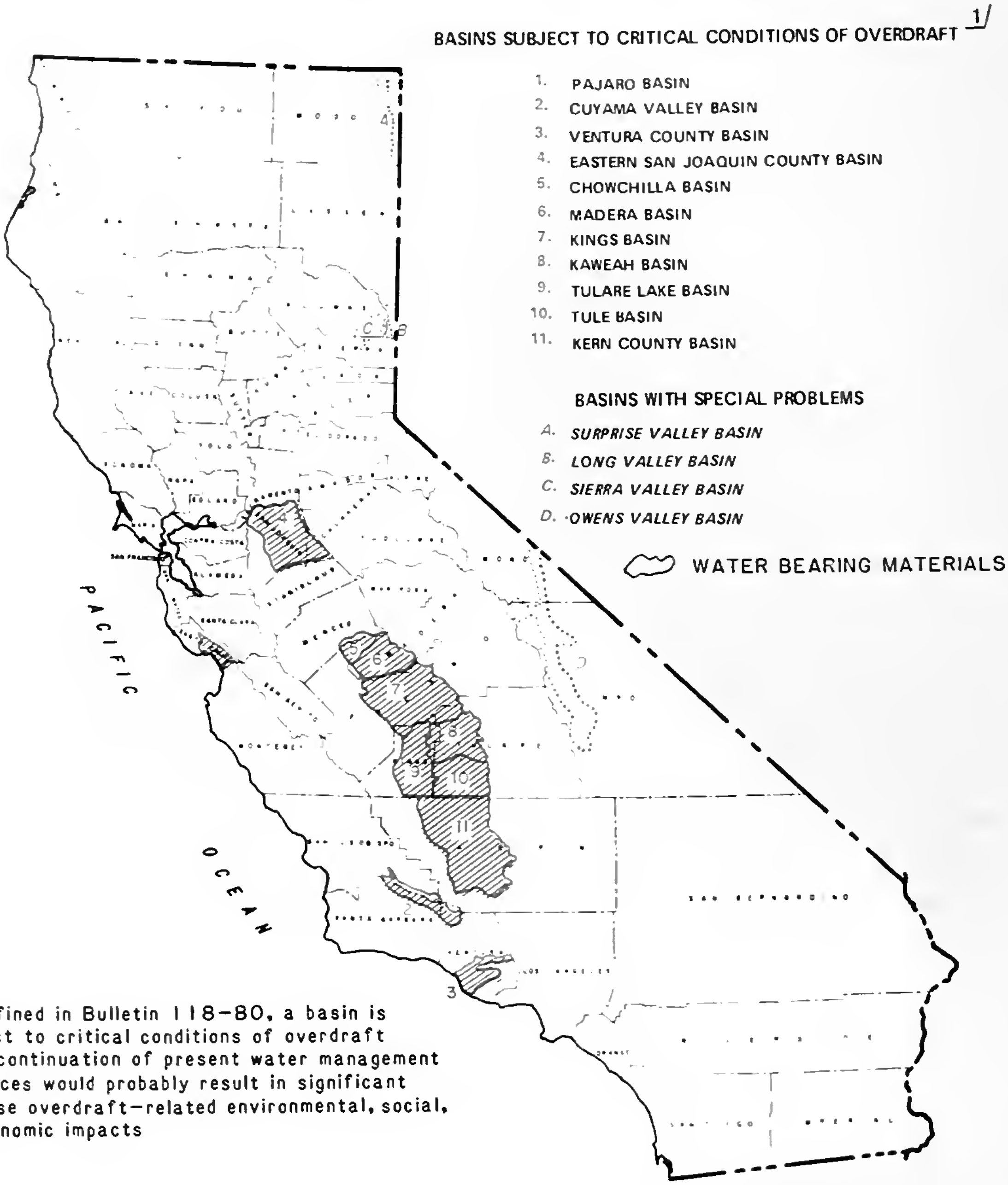
Water in storage is the portion of total storage capacity that is presently full of water. *Available storage capacity* is the remaining portion, which is empty and available for the storage of water. The annual variations in ground water recharge necessitate *regulatory storage capacity* to sustain a uniform annual yield.

Some of the storage capacity may also serve to regulate local recharge. When the available storage capacity is larger than is needed to regulate recharge, additional water from other sources may be stored in that basin without the risk of spill to surface water flows.

Usable storage capacity is storage capacity that is capable of yielding water to wells economically and of being readily recharged (filled). Two decades ago, when many of the estimates of usable storage capacity were made, the economical limit in many inland areas was considered to be a depth of 200 feet, and, in other inland areas, it was the base of the fresh water in a ground water basin. For coastal basins, the maximum economical limit of usable storage capacity was considered to be sea level. Some of those earlier assumptions are now no longer valid, and the data that are available are very conservative.

* Specific yield is the amount of water by volume released from a volume of saturated material under the force of gravity. It is expressed as a ratio or percentage.

Figure 25. BASINS SUBJECT TO CRITICAL CONDITIONS OF OVERDRAFT OR WITH SPECIAL PROBLEMS



1/ As defined in Bulletin 118-80, a basin is subject to critical conditions of overdraft when continuation of present water management practices would probably result in significant adverse overdraft-related environmental, social, or economic impacts

Reclaimed Urban Waste Water

Waste water reclamation is the reuse of treated urban waste water for beneficial purposes. Biological treatment is involved and, in some cases, desalting may also be needed. Some key considerations, such as dissolved mineral levels, health concerns, costs, and institutional conflicts, have strongly affected policy decisions by local agencies in pursuing waste water reclamation.

There are two terms used to designate waste water reclamation: intentional and incidental. Reclamation of waste water that would otherwise be discharged to salt sinks (such as the ocean or saline estuaries) or reclamation of water so degraded that it cannot be discharged to fresh water, would be intentional and would create a "new" water supply. On the other hand, some of the urban water used in California is returned to the fresh water cycle after it has been treated. This is termed incidental reclamation because additional use made of this water is only incidental to waste water treatment and disposal.

Up to 50 percent of an urban supply is used for landscaping and is transpired or evaporated or percolates into the ground. The remainder is collected and conveyed to waste treatment plants. Not all the collected waste water can be reclaimed, however. Twenty to 30 percent is needed to carry off concentrated wastes. Accordingly, only 20 to 30 percent of the original supply may be available for reclamation.

Mineral quality of fresh-water supplies is important in evaluating reclamation. A single cycle of water use in an urban area normally adds about 300 milligrams of salts per litre of water. The recommended upper limit for salts in municipal supplies is 500 milligrams per litre (mg/L), but up to 1,000 mg/L is acceptable. A large share of the urban water supply in the coastal area of Southern California is derived from the Colorado River and has a salt content of around 750 mg/L. A single use would concentrate the salt sufficiently to exceed the acceptable limit, and reclaimed water would have to be desalted or blended with less saline water. Water delivered by the SWP to Southern California has a monthly average of only 100 to 440 mg/L. With an increasingly greater share of the water used in Southern California supplied by the SWP, mineral concentrations in the resulting waste water will be reduced.

Present Waste Water Reclamation. The higher levels of waste water treatment, motivated largely by public health, esthetic, and ecological concerns, have resulted in more complete treatment of wastes before they are discharged. This treatment makes the waste flows more suitable for reclamation and reuse and lowers the incremental cost of reclamation. The competitive position of waste water reclamation is thereby enhanced in comparison with alternative water supply sources. Increasing demands on the limited water supplies in some areas have also encouraged waste water reclamation.

Almost 3.4 million acre-feet of urban waste water was treated in 1980 in California. The disposition of this treated water (Table 12) shows that 2.4 million acre-feet of treated waste effluent produced was discharged into salt sinks. As shown, statewide total

TABLE 12
DISPOSITION OF TREATED URBAN WASTE WATER BY HYDROLOGIC STUDY AREA
1980
(In 1,000s of acre-feet)

HSA	*Waste Water Reclaimed*			*Waste Water Discharged to Salt Sinks*	*Total[1] Waste Water Produced*	*Percent Waste Water Reclaimed*
	Intentional	*Incidental*	*Total*			
NC	9	3	12	62	74	16
SF	10	3	13	568	584	2
CC	9	11	20	93	113	18
LA	59	17	76	1,003	1,079	7
SA	29	74	103	383	486	21
SD	9	—	9	275	284	3
SB	17	292	309	—	329	94
SJ	21	141	162	—	176	92
TL	67	41	108	8	126	86
NL	5	6	11	—	11	100
SL	9	14	23	—	46	50
CR	3	10	13	44	58	24
TOTAL	247	612	859	2,436	3,366	26

[1] This total also includes evaporation from waste water flows.

reclamation (the sum of the intentional and incidental reclamation) is 26 percent of the total treated urban waste water produced. However, a very large percentage of total waste water production in the inland Hydrologic Study Areas is reused—about 100 percent in those HSAs that do not discharge waste water to salt sinks. Thus, most waste water discharge in these inland areas is reused, even though only small quantities of waste water are intentionally reclaimed.

At present, intentionally reclaimed water is used chiefly for crop irrigation, industrial purposes, municipal irrigation, wildlife habitat, and ground water recharge. The major use of water resulting from intentional reclamation of urban wastes in 1979, as reported by municipal, federal, and private agencies, is for irrigation—137,600 acre-feet out of a total of 197,600 acre-feet—as shown in Table 13. Crop irrigation is the largest single use—106,900 acre-feet or 54 percent of the total. Almost 84,000 acre-feet is used in the three small HSAs in the South Coastal region.

Agricultural uses include irrigation of (1) pasture; (2) fodder, fiber, and seed crops; (3) crops that are grown well above the ground, and out of the reach of the water, such as fruits, nuts, and grapes; and (4) other crops that are processed so that pathogenic organisms are destroyed before human consumption.

Use of intentionally reclaimed water to recharge ground water basins—23,900 acre-feet in 1979—not only provides storage but also some natural treatment as it percolates to an underground domestic supply. Use can also include injection into the ground in coastal areas to form a sea-water intrusion barrier.

Industrial uses of reclaimed water—4,600 acre-feet in 1979—include cooling water, process wash water, boiler feed water, quenching spray water, fire protection, and secondary product recovery. These are carried out chiefly at metallurgical manufacturing and fabrication plants, electric power generation plants, oil refineries and petrochemical plants, and mines and quarries.

The use of reclaimed water for municipal irrigation and recreational pursuits includes (1) irrigation of parks, freeway landscapes, golf courses, and athletic fields; (2) creation of scenic and ornamental lakes and ponds; (3) maintenance of recreational lakes for picnicking, boating, and swimming; (4) irrigation of landscapes in commercial and industrial developments; and (5) maintenance of marshes and ponds for wildlife habitat and fish.

Limitations and Constraints. At this time, significant health concerns greatly limit urban use of reclaimed water. These concerns arise because of stable organic compounds and viruses that may remain in some municipal waste water after treatment. Development and use of a wide range of organic compounds for industrial, commercial, agricultural, and household uses have influenced the quality of some water supplies. Many of the complex compounds are stable; that is, they persist for a long time and they do not break down into simpler nontoxic forms. The long-term effect of ingesting even minute amounts of some stable organic compounds is uncertain; therefore, efforts are made to avoid the use of water containing these compounds where that use may be detrimental to public health.

TABLE 13

REPORTED INTENTIONAL USE OF RECLAIMED WATER BY HYDROLOGIC STUDY AREA

1979

(In acre-feet)

	Industrial		*Irrigation*			*Other Uses*					
HSA	*Power Plant Cooling*	*Other*	*Crops*	*Landscape*	*Golf Course*	*Ornamental Lakes*	*Ground Water Recharge*	*Recreation*	*Wildlife Habitat*	*Unclassified*	*TOTAL*
NC	—	800	8,000	—	—	—	—	—	—	600	9,400
SF	—	300	6,500	1,200	200	—	—	—	100	2,100	10,400
CC	—	—	8,800	200	—	—	—	—	—	100	9,100
LA	—	—	1,700	11,400	13,600	—	12,800	—	—	6,300	45,800
SA	—	400	3,700	—	—	—	10,400	—	—	14,500	29,000
SD	—	—	100	—	2,000	900	700	—	3,700	1,700	9,100
SB	—	1,600	14,200	200	—	1,100	—	—	—	—	17,100
SJ	200	—	20,300	100	—	—	—	—	—	—	20,600
TL	—	—	34,500	—	—	—	—	—	—	—	34,500
NL	—	—	5,400	—	—	—	—	—	200	—	5,600
SL	—	400	2,000	300	800	—	—	200	—	—	3,700
CR	—	900	1,700	—	700	—	—	—	—	—	3,300
TOTAL	200	4,400	106,900	13,400	17,300	2,000	23,900	200	4,000	25,300	197,600

Data in this table are based on responses to a 1980 survey of California waste water treatment plants by the Department of Water Resources. The table is not a complete accounting of intentional use.

Health officials reject direct distribution of reclaimed water for human consumption. They also have severely restricted the use of reclaimed water to recharge ground water basins drawn on for human use because of the possible effects of stable organic compounds and heavy metals. Because ground water migrates slowly and does not intermix well, reclaimed water introduced into a ground water basin would move away from the area of entry in a body and might not dissipate for many years.

Distribution of fresh-water supplies and treatment and disposal of municipal waste water are usually handled by different agencies with different objectives. Because of this, institutional constraints on marketing the reclaimed water have tended to inhibit its reclamation and reuse. Water supply agencies generally build a new pipeline to take the reclaimed water from the waste water treatment plant to the areas of use. In marketing this water, these agencies may be burdened with the costs of maintaining dual water distribution systems, one for fresh water and one for reclaimed water. In addition, the price of reclaimed water is often established through negotiation, and the ultimate users may pay less for it then they do for fresh water. This occurs because they also have the added expense of operating dual water systems and controlling water use to meet public health criteria.

Energy Use. Since a water reclamation project provides water to a local area, less energy may be consumed to operate it than to import water to the area from a distant source. In Southern California, for instance, water reclamation projects use from 200 to 2,200 kilowatthours per acre-foot (kWh/ac-ft), while about 2,900 kWh/ac-ft is required to transport SWP water from the Delta. The actual energy required must be determined on a case-by-case basis and depends on the amount of treatment the waste water needs and the pumping lift required for distribution and storage of the water (reclamation plants are usually situated at elevations below that of the place of use).

Current Costs. Because of the unique nature of each water reclamation project, costs must also be determined case by case. An economical project should produce water at a cost that does not exceed the cost of project alternatives, presently $200–350 per acre-foot in most areas of the State.

Water Prices

More than 2,500 agencies in California are engaged in selling water: over 500 independent special districts, 257 municipal waterworks, about 400 private companies regulated by the State Public Utilities Commission, and about 1,200 mutual water companies. Together these represent more than 30 legally distinct types of entities. Each water purveyor distributes water within a pricing framework based on its own policies, costs, objectives, and institutional constraints. As a result, a great number of water pricing systems currently are in use in California. Water prices vary from less than $1.00 to nearly $200 per acre-foot for some agricultural water and from less than $40 to more than $400 per acre-foot for urban water. Water often passes through one or more wholesalers and a retailer before it reaches the ultimate consumer.

Policies of water purveyors are important factors in pricing. For example, the policy of the State Water Project is to require full repayment by the users of all costs associated with delivery of the allocated water, and the SWP water contracts require that this be done. In keeping with federal reclamation policy, the irrigation water charges by the Central Valley Project do not include repayment of interest on construction costs of the project.

Because of the large number of water purveyors and the wide range in pricing structures, it is difficult to develop and present an overall picture of water pricing. Based on available data, a weighted average water rate and the range of water rates for both urban and agricultural water is shown by county in Table 14. It also includes costs for self-produced water for the agricultural sector. (Self-produced water is either pumped from wells or diverted directly from a stream.) Examination of the table reveals that (1) agricultural water is priced highest in the South Coastal region HSAs and lowest in the Sacramento HSA portion of the Central Valley; and (2) urban water is generally priced higher than agricultural water. This is partly because urban supply systems are more complex and involve greater costs for local facilities for system regulation, treatment plants, distribution systems, water meters, and system operation, including meter reading and customer billing. In addition, in some cases, the water rate includes a charge for waste water treatment.

TABLE 14
AVERAGE URBAN AND AGRICULTURAL RETAIL WATER PRICES BY COUNTY
(In dollars per acre-foot)

County	Urban Prices[1]	Range	Agricultural Prices[2]	Range
Alameda	265	221–369	N/A	N/A
Alpine	260	261	N/A	N/A
Amador	230	88–403	N/A	N/A
Butte	130	94–320	5.00	1.00–12.00
Calaveras	210	210	N/A	N/A
Colusa	110	99–149	2.90	1.00–12.00
Contra Costa	245	197–261	5.30	2.00–9.00
Del Norte	230	205–324	N/A	N/A
El Dorado	220	169–261	N/A	N/A
Fresno	65	61–80	14.90	1.00–65.00
Glenn	140	70–22	4.20	1.00–12.00
Humboldt	195	173–289	N/A	N/A
Imperial	175	147–192	7.50	7.50
Inyo	110	0–225	12.60	10.00–37.60
Kern	175	148–193	31.00	6.60–78.00
Kings	140	137–149	20.50	2.70–37.20
Lake	170	165	15.90	3.00–19.00
Lassen	190	189	6.30	4.00–10.00
Los Angeles	210	108–273	36.50	30.00–86.00
Madera	105	82–117	11.50	3.70–18.60
Marin	340	283–394	N/A	N/A
Mariposa	210	211	N/A	N/A
Mendocino	170	168–175	N/A	N/A
Merced	65	61–78	9.40	4.00–21.00
Modoc	155	156	10.50	5.50–44.00
Mono	130	128	14.70	3.00–25.70
Monterey	195	165–260	38.00	19.80–55.00
Napa	310	305–318	N/A	N/A
Nevada	145	126–194	8.60	8.00–20.00
Orange	195	147–236	63.00	40.00–75.00
Placer	160	127–188	7.20	2.00–24.00
Plumas	220	220	2.80	1.00–16.00
Riverside	190	156–248	12.00	3.40–133.00
Sacramento	65	40–81	5.50	1.00–20.00
San Benito	175	152–208	18.90	1.50–19.80
San Bernardino	150	139–166	36.00	12.00–52.00
San Diego	265	223–346	145.00	40.00–192.00
San Francisco	200	200	N/A	N/A
San Joaquin	180	96–303	6.90	1.50–16.00
San Luis Obispo	305	247–323	32.00	28.50–35.00
San Mateo	285	164–344	N/A	N/A
Santa Barbara	315	195–401	45.00	25.30–109.00
Santa Clara	235	169–278	21.00	11.00–30.00
Santa Cruz	265	264–281	N/A	N/A
Shasta	145	109–200	5.00	2.90–10.00
Sierra	110	85–118	N/A	N/A
Siskiyou	165	150–188	5.20	2.00–10.00
Solano	200	153–351	6.70	2.00–20.00
Sonoma	245	225–288	N/A	N/A
Stanislaus	80	54–173	3.20	0.65–6.90

TABLE 14—*Continued*

AVERAGE URBAN AND AGRICULTURAL RETAIL WATER PRICES BY COUNTY

(In dollars per acre-foot)

County	Urban Prices[1]	Range	Agricultural Prices[2]	Range
Sutter	145	133–181	4 10	1.00–6.50
Tehama	135	132–145	7.60	2.70–11.37
Trinity	330	277–425	N/A	N/A
Tulare	130	108–137	14.00	3.40–23.30
Tuolumne	280	279	N/A	N/A
Ventura	240	206–283	31.50	14 00–78.00
Yolo	70	56–97	6.60	1.00–20.00
Yuba	110	100–120	5.80	0.75–14.00

[1] The average urban water prices shown in this table are approximate weighted averages based on a recent DWR survey of 107 cities and service areas The figures represent the 1980 or 1981 cost per acre-foot of water for a family using three-fourths acre-foot of water each year

[2] The average agricultural water prices are approximate weighted averages based on a recent DWR survey of 161 water districts and other water sources The price figures include per-acre assessments and represent 1979, 1980, or 1981 They represent the rates farmers pay for irrigation district water, and the estimated costs of self-produced water, such as ground water and direct diversion of river water

N/A = Not available

PUMPING ENERGY USED FOR CALIFORNIA'S WATER SUPPLIES

A significant amount of electricity is used by pumps to produce, transport, and distribute water to homes, businesses, factories, and farms. In turn, many utility districts and water agencies produce hydroelectric energy when they store and deliver water, even though pumping may be required as part of the system.

Examples of the energy required to provide water supplies throughout California are shown in Table 15. There are some significant omissions; the table does not include information on some major producers of water, such as the Los Angeles Department of Water and Power; the East Bay Municipal Utility District; the San Francisco Water Department; the Imperial, Modesto, and Turlock Irrigation Districts; and the Coachella Valley Water District. The systems of these water agencies generate more electricity than they consume since they are basically aqueducts and canals that are gravity-flow systems. Table 15 is based on 1.75 kilowatthours per acre-foot (kWh/ac-ft) per foot of lift. For the energy-using systems shown in the table, kilowatthours per acre-foot range from 25 for diversion from a stream in the Central Valley to about 3,000 kWh/ac-ft for SWP supplies in Southern California. The information in this table is given to provide a representation of energy used in furnishing water supplies. The data are not sufficient to summarize on the basis of regional or statewide averages.

A few conclusions can be drawn from the information in Table 15. Areas with expensive water (see Table 14) also have water with relatively high kWh/ac-ft ratios. An acre-foot of imported water generally uses more electricity than an acre-foot of local surface water.

TABLE 15

EXAMPLES OF PUMPING ENERGY USED FOR WATER SUPPLY

Region	Water Source	Year	Average kWh Per Acre-Foot
Southern California			
Metropolitan Water District	Colorado River Aqueduct	1980	2,050
	SWP	1980	2,950
Orange County	Ground water	1975	175
Chino Basin, West San Bernardino County	Ground water	1981	630
San Francisco Bay			
South Bay Aqueduct	SWP	1979	840
Entire Bay Area	Ground water	1975	155
Central Valley			
Central Valley Area	CVP	1972	360
	River diversion	1981	25
Lost Hills WSD, Kern County	SWP	1980	550
Wheeler Ridge-Maricopa WSD, Kern County	SWP	1980	1,100
Butte County	Ground water	1979	90
Sacramento County	Ground water	1979	210
Fresno County	Ground water	1979	180
Kern County	Ground water	1979	440
Salinas Valley			
Salinas River Valley Area	Ground water	1975	100

TABLE 16
TOTAL APPLIED WATER AND NET WATER USE BY HYDROLOGIC STUDY AREA
1980
(In 1,000s of acre-feet)

	NC	SF	CC	LA	SA	SD	SB	SJ	TL	NL	SL	CR	TOTAL
APPLIED WATER													
Agriculture	821	121	1,189	348	412	228	9,223	7,474	11,424	442	493	3,460	35,635
Urban	153	967	231	1,654	734	389	570	403	425	23	95	118	5,762
Wildlife	260	100	–	7	–	5	167	86	45	10	3	17	700
Recreation	1	2	2	1	2	2	3	10	7	1	9	3	43
Energy Production	0	6	7	7	9	–	–	15	10	–	2	3	59
TOTAL	1,235	1,196	1,429	2,017	1,151	624	9,963	7,988	11,911	476	602	3,601	42,199
NET WATER USE													
Agriculture	714	121	902	276	320	198	6,682	5,892	7,781	387	338	3,434	27,045
Urban	151	967	188	1,534	586	389	493	249	236	23	60	102	4,978
Wildlife	215	94	–	7	–	5	157	64	31	10	3	17	603
Recreation	1	2	2	1	2	2	3	10	7	1	9	3	43
Energy Production	–	6	7	7	9	–	–	15	10	–	2	3	59
Conveyance Losses	–	14	–	81	45	40	129	111	123	–	7	543	1,093
TOTAL	1,081	1,204	1,099	1,906	962	634	7,464	6,341	8,188	421	419	4,102	33,821

TABLE 17
CHANGES IN NET WATER USE BY REGION
1972 to 1980
(In 1,000s of acre-feet)

Regions	*1972*	*1980*	*Amount of Change*	*Percent Change*
North Coast (North Coast and San Francisco Bay HSAs)	2,210	2,280	+70	+3
Central Coast HSA	950	1,100	+150	+16
South Coast (Los Angeles, Santa Ana, and San Diego HSAs)	3,080	3,500	+420	+14
Central Valley (Sacramento, San Joaquin, and Tulare Lake HSAs)	20,000	22,000	+2,000	+10
North Lahontan HSA	430	420	–10	–2
Southeastern Desert (South Lahontan and Colorado River HSAs)	4,350	4,520	+170	+4
TOTAL	31,020	33,820	+2,810	+9

TABLE 18
DEPENDABLE WATER SUPPLIES, 1980 LEVEL OF DEVELOPMENT BY HYDROLOGIC STUDY AREA
(In 1,000s of acre-feet)

	NC	SF	CC	LA	SA	SD	SB	SJ	TL	NL	SL	CR	TOTAL
PRESENT USE OF DEPENDABLE SUPPLY													
Local Surface	368	228	39	29	93	37	2,886	3,055	2,199	312	44	4	9,274
Imports by Locals	2	454	—	752	290	290	9	—	—	11	—	—	1,808
Ground Water [1]	243	211	768	483	402	77	1,798	972	551	88	178	68	5,839
CVP	—	81	—	—	—	—	2,422	1,838	2,736	—	—	—	7,077
Other Federal	458	56	54	20	—	—	259	55	243	—	—	3,970	5,115
SWP	—	157 [2]	—	481	138	221	—	8	1,536 [2]	—	85	30	2,656
Waste Water Reclamation	9	10	9	59	29	9	17	21	67	5	9	3	247
Subtotal	1,080	1,197	870	1,824	952	634	7,371	5,949	7,332	416	316	4,075	32,016
RESERVE SURFACE WATER SUPPLY	9	138	17	164	203	46	535	191	56	17	33	4	1,413
TOTAL DEVELOPED WATER SUPPLY	1,089	1,335	887	1,988	1,155	680	7,906	6,140	7,388	433	349	4,079	33,429

[1] Not including overdraft [2] Includes SWP surplus water deliveries

Statewide Hydrologic Balance

The relationship between water use and water supplies in California is determined through analysis of the hydrologic balance. The major components of the balances for each HSA are summarized in tables appearing later in this chapter that show applied water, net water use, and developed water supplies in 1980. The full complexity of a statewide hydrologic balance is illustrated at the end of this section.

A summary of applied water in 1980 (Table 16) indicates the quantities of water delivered to the point of use, such as municipal system, factory, or farm headgate. The summary of net water use in 1980, also shown, indicates the water supplies actually needed to support this level of development. Net water use is considerably less than applied water, primarily because of the extensive reuse that takes place. Net water use is the amount of water required to meet the evapotranspiration of applied water and the irrecoverable distribution system losses, as well as the outflow from the area.

Between 1972 and 1980, a substantial increase in net water use occurred—2.8 million acre-feet—mostly in the Central Valley. Net water use in 1972, as presented in Bulletin 160-74, is compared in Table 17 by regions (HSAs or combinations of HSAs), with the current estimate of net water use for 1980 (also shown in Table 16). In the Central Valley, the increase was 2 million acre-feet, a 10-percent increase from 1972 to 1980. This increase was mostly in support of irrigated agriculture. The other region of substantial increase was in the South Coastal region, where there was additional net water use of 420,000 acre-feet, mostly for urban purposes.

Statewide, the total annual long-term dependable developed water supply is 33,429,000 acre-feet, of which 32,016,000 acre-feet is currently used. This leaves 1,413,000 acre-feet as a reserve developed surface water supply.

The dependable water supplies used to meet the net water uses are summarized in Table 18. The reserve surface water supply indicated in the table represents the portion of developed water supply from specific water projects where the use by the service areas for those projects has not yet reached the full capability of the water supply. In general, the reserve surface water supplies indicated are committed to the designated service areas and are not available to meet needs of other areas, even temporarily, because of a lack of conveyance systems and of institutional arrangements to make the water available.

The statewide summary of net water use, present use of dependable water supplies, ground water overdraft, and reserve supply is presented in Table 19. The Sacramento HSA has the largest net use of dependable water supply and the largest reserve supply, 7.4 million acre-feet and 535,000 acre-feet, respectively. The Tulare Lake HSA has the second largest use of dependable supply; but, with the largest net water use, 8.2 million acre-feet, it also has the largest overdraft.

Statewide ground water overdraft is estimated at 1.8 million acre-feet annually. Table 19 indicates that ground water overdraft occurs in some HSAs where reserve supplies are present. The most notable example of this is the San Joaquin HSA because, as indicated above, local areas where the ground water overdraft occurs do not have access to the reserve supplies.

One of the major water problems in California is the lack of natural surface water supplies in the areas where the most development using water has taken place. The extensive conveyance systems necessary to move the water to the area of use are shown on Plate 1 and are generalized in Figure 26, together with the substantial quantities of water transferred. More than 18 million of California's 23.8 million people live in the coastal metropolitan areas of San Francisco Bay and the South Coastal region (1980). This population is supported substantially by imported water supplies. Large imports of water are also required to sustain the current level of irrigated agriculture in the San Joaquin Valley.

TABLE 19

NET WATER USE AND WATER SUPPLY SUMMARY BY HYDROLOGIC STUDY AREA

1980

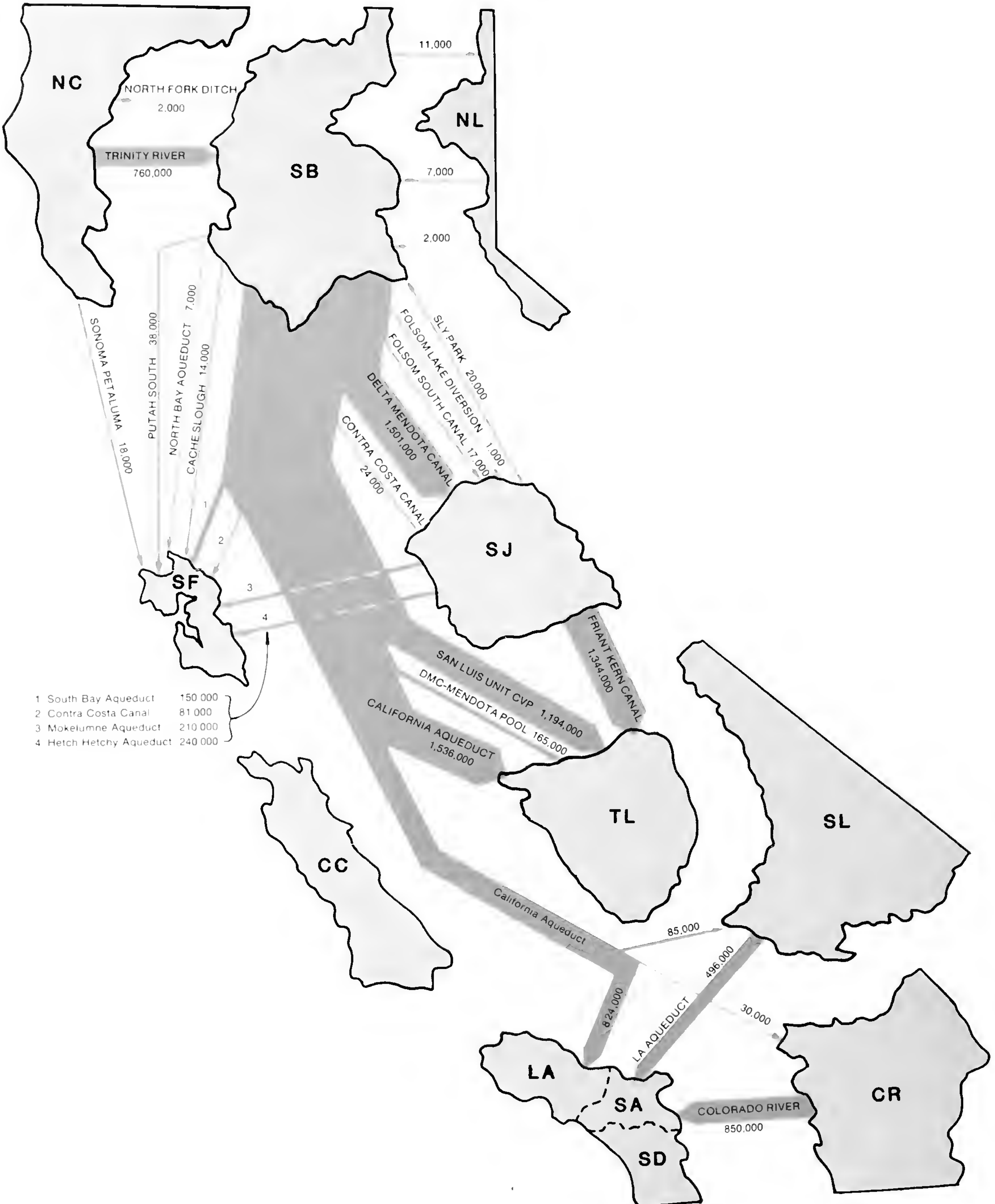
(In 1,000s of acre-feet)

	NC	*SF*	*CC*	*LA*	*SA*	*SD*	*SB*	*SJ*	*TL*	*NL*	*SL*	*CR*	*TOTAL*
Net Water Use	1,081	1,204	1,099	1,906	962	634	7,464	6,341	8,188	421	419	4,102	33,821
Present Use of Dependable Supply	1,080	1,197 [2]	870	1,824	952	634	7,371	5,949	7,332 [2]	416	316	4,075	32,016
Ground Water Overdraft	—	7	224	82	10	—	85	391	856	5	103	27	1,790
Shortage [1]	1	—	5	—	—	—	8	1	—	—	—	—	15
Reserve Surface Water Supply	9	138	17	164	203	46	535	191	56	17	33	4	1,413

[1] Shortage in urban water supply
[2] Includes SWP surplus water deliveries

Figure 26. EXISTING INTRASTATE WATER TRANSFERS AT 1980 LEVEL OF DEVELOPMENT

ACRE-FEET PER YEAR



The four regions that import significant amounts of water and now have, or previously have had, substantial ground water overdraft are shown in Table 20. In all these regions, the imported supplies have been developed to offset overdraft conditions and meet anticipated future needs. In the South Coastal region, ground water basins are now mostly managed. Many of them have been adjudicated, and overdraft has been largely eliminated. However, the area imports 62 percent of its net water supply, as does the San Francisco Bay HSA. The Tulare Lake HSA has the largest ground water overdraft—about 850,000 acre-feet per year—and imports 36 percent of its net water supply. Most of the net water use in the South Coastal region and the San Francisco Bay HSA is for urban purposes, while in the Tulare Lake HSA, it is primarily for irrigated agriculture.

TABLE 20
COMPARISON OF LOCALLY DEVELOPED AND IMPORTED NET WATER SUPPLIES
1980
(In percent)

Location	*Water Supply Developed within the Area*	*Water Supply Imported*
San Francisco Bay HSA	38	62
South Coast Region (Los Angeles, Santa Ana, and San Diego HSAs)	38	62
San Joaquin HSA	76	24
Tulare Lake HSA	64 [1]	36

[1] CVP water delivered through Friant-Kern Canal was considered as a water supply developed within the area

STATEWIDE HYDROLOGIC BALANCE NETWORK

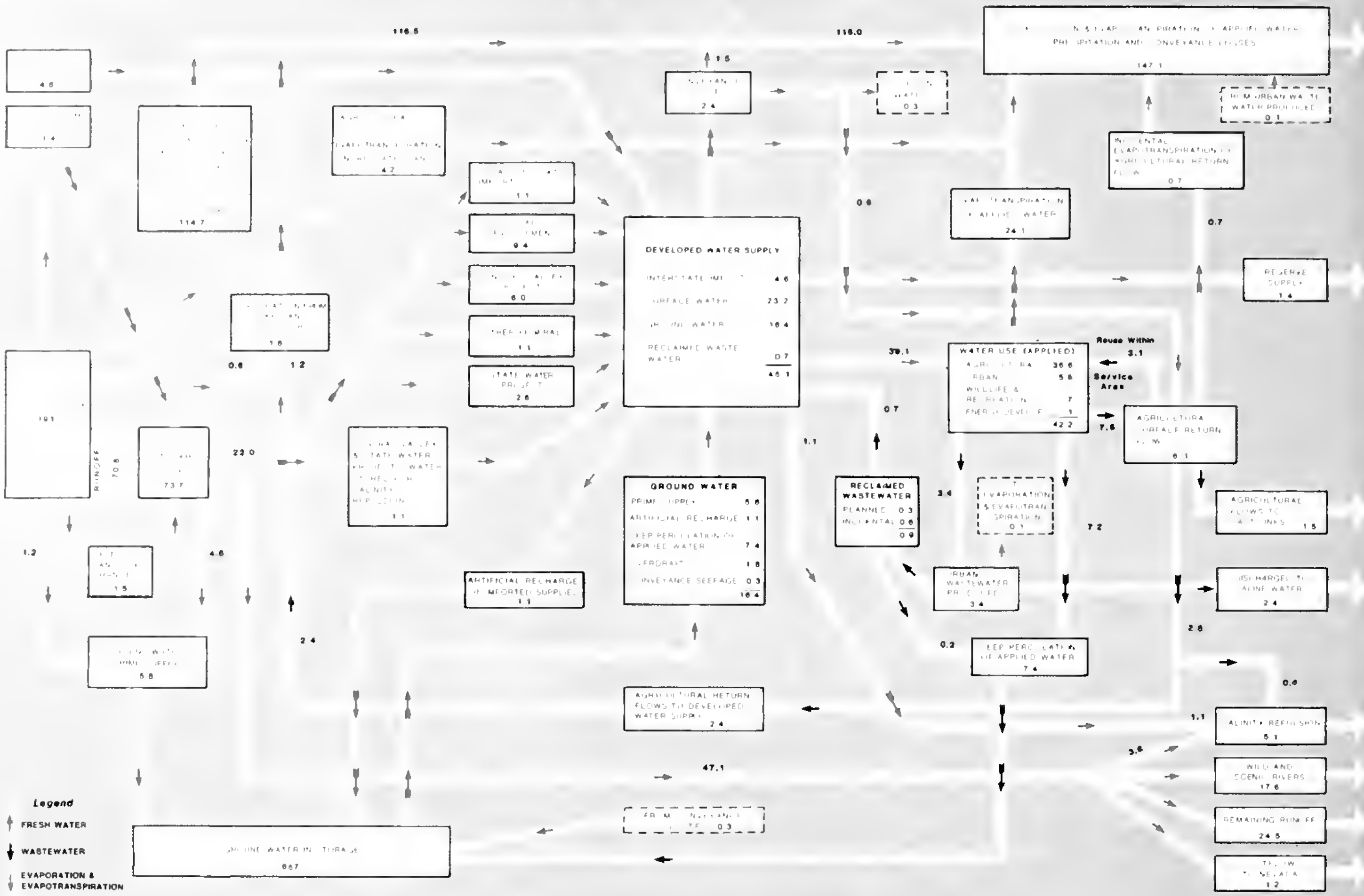
California's natural water supplies are derived from an average annual statewide precipitation of 193 million acre-feet. This amount translates to an average depth of nearly 2 feet, varying from nearly zero to more than 100 inches across the State. About 60 percent of this precipitation is consumed through evaporation and transpiration by trees, brush, and other vegetation. Most of the remainder comprises the State's average annual runoff, 71 million acre-feet. Of this, more than 4 million acre-feet percolates from stream channels to ground water basins. This amount is about 80 percent of the total prime supply to ground water in California. Most of this 80 percent is naturally recharged to ground water. The rest is local surface supplies that are recharged by artificial means. The remaining 20 percent is derived from precipitation percolating directly to the ground water through the soil. Average annual precipitation and runoff by Hydrologic Study Areas are shown in the series of maps appearing in "Summaries of Hydrologic Study Areas" in this chapter.

The overall balance between water use and the water resources of California is shown in Figure 27. The amounts shown represent average hydrologic conditions, current water development, and 1980 level of water use in relation to:

- Natural water resources of California, both surface and ground water.
- Interstate imports and exports.
- Developed water supplies.
- Surface water and ground water.
- Applied water.
- Consumptive use of precipitation and developed water supplies.
- Reuse of water.
- Final outflows to the ocean and other salt sinks.

Figure 27. HYDROLOGIC BALANCE NETWORK FOR CALIFORNIA 1980

IN MILLION ACRE-FEET



DESCRIPTIONS OF COMPONENTS OF THE HYDROLOGIC BALANCE NETWORK FOR CALIFORNIA (Figure 27)

Sequence on Chart Is
Top to Bottom and
Left to Right

1. **Colorado River**—Representative 1980 level of use of water diverted from the Colorado River by The Metropolitan Water District of Southern California, Imperial Irrigation District, Coachella Valley Water District, Palo Verde Irrigation District, the Yuma Project, and others under California's entitlement to use of Colorado River water.

2. **Inflow from Oregon**—Klamath River inflow from Oregon.

3. **Precipitation**—Long-term average annual precipitation falling in California.

4. **Runoff**—The portion of long-term average annual precipitation which runs off the land and makes up the natural flow in rivers and streams.

5. **Effect of Land Use Changes**—The portion of average annual precipitation that would have been used by natural vegetation but now contributes to runoff. This is a result of roads, paved areas, building roofs, land drainage systems, fields developed for irrigation, and other changes in land use.

6. **Ground Water Prime Supply**—The long-term average annual percolation to the major ground water basins from precipitation falling on the land and from flows in rivers and streams. Also includes recharge from local sources that has been enhanced by construction of spreading grounds and other structural devices. Recharge of imported and reclaimed water is not included.

7. **Evaporation and Evapotranspiration from Forest, Rangeland, Unirrigated Agriculture, Native Vegetation, and Other Lands**—The statewide evaporation of precipitation from land surfaces and the evapotranspiration of precipitation by nonirrigated trees, brush, dry-farmed crops, grass, and other plants.

8. **Total Streamflow**—The long-term average annual natural streamflow and the increase in streamflow due to land use changes.

9. **Ground Water in Storage**—The estimated total fresh water stored in the major ground water basins within the State.

10. **Evaporation from Lakes and Reservoirs**—The average annual surface evaporation from natural lakes and constructed surface water storage reservoirs.

11. **Agriculturally Effective Evapotranspiration on Irrigated Lands**—Average annual precipitation used by crops planted in developed irrigated land areas.

12. **Central Valley and State Water Projects, Water Stored for Salinity Repulsion**—Represents release of carryover storage (part of the firm yield) of these two projects to supplement natural flows to meet outflow requirements for protection of beneficial uses in the Sacramento-San Joaquin River Delta.

13. **Local (In State) Imports**—The average annual inter-watershed transfers of water supply within the State.

14. **Local Development**—The average annual surface water supplies of individuals and from local water agency water projects. It includes direct deliveries of water from streamflows, as well as local water storage facilities. It excludes artificial recharge of local water to ground water basins (part of ground water prime supply).

15. **Central Valley Project**—The sum of estimated deliveries, conveyance losses, and available reserves in 1980 from the Central Valley Project.

16. **Other Federal**—The sum of estimated deliveries and available reserves in 1980 from federal projects other than the Central Valley Project.

17. **State Water Project**—The sum of estimated deliveries, conveyance losses, and available reserves from the existing facilities of the State Water Project.

18. **Artificial Recharge of Imported Supplies**—The average annual contribution from imported water supplies and planned waste water reclamation projects. Does not include recharge of local supplies to ground water recharge by specific recharge project.

19. **Conveyance Losses**—The average loss from major water supply conveyance systems to evaporation, seepage from unlined canals, and evapotranspiration by vegetation in and near canals.

20. **Developed Water Supply**—The total developed water supply, including surface water supplies, ground water pumped, imports from the Colorado River, and planned and incidental waste water reclamation.

21. **Ground Water**—A summary of the sources of ground water as part of the developed water supply.

22. **Agricultural Return Flows to Developed Water Supply**—Represents surface return flows from irrigated agriculture to stream channels that are available for use outside the local service area.

23. **From Conveyance Losses**—That portion of conveyance losses that seeps into ground water supplies.

24. **Reclaimed Waste Water**—The planned renovation of waste water for specific beneficial purposes and the incidental reuse of treated waste water flows that return to streamflows and ground water basins.

25. **To Ground Water**—That portion of the conveyance losses attributable to seepage from canals that becomes available as ground water. (This is the same water as that shown in 23 above.)

26. **Urban Waste Water Produced**—Represents the flow from urban waste water treatment plants.

27. **Evapotranspiration of Applied Water**—The applied water consumptively used through evaporation and transpiration by agricultural crops, urban areas, wildfowl management areas, parks and other recreation areas, and energy production.

28. **Water Use (Applied)**—Represents the applied water for irrigated agriculture, urban areas, wildfowl management areas, nonurban parks and recreation areas, and energy production.

29. **Evaporation and Evapotranspiration of Applied Water, Precipitation, and Conveyance Losses**—The total of all evaporation and evapotranspiration under average natural conditions and 1980 level of applied water.

30. **Deep Percolation of Applied Water**—Represents that portion of applied water for agriculture and urban purposes that percolates to the ground water, including the water used for leaching accumulated salts from the root zone.

31. **To Evaporation and Evapotranspiration**—That portion of the urban waste water produced that evaporates from evaporation and percolation ponds.

32. **Reuse Within Service Area**—Represents reuse of irrigation systems tailwater and return flows to local distribution systems and streams within a unit geographic study area; in this case, does not include reuse of excess applied water that percolates to ground water.

33. **Incidental Evapotranspiration of Agricultural Return Flows**—Represents the evapotranspiration by weeds and other vegetation in fringes of fields and in and near the agricultural drains and sump areas.

34. **Agricultural Surface Return Flows**—Represents the flows from applied irrigation water and some returns of conveyance losses that return to the developed surface water supply, are discharged to salt sinks, or are consumed by riparian plants.

35. **From Urban Waste Water Produced**—The portion of urban waste water that is lost to evaporation.

36. **Reserve Supply**—Developed but presently unused surface water supply available to certain portions of a Hydrologic Study Area to meet planned future water needs; usually the supply is not available to other areas needing additional water because of a lack of physical facilities and/or institutional arrangements.

The reserves include the sum of the reserves in each Planning Subarea (PSA) from:

- Local development and imports
- SWP
- CVP
- Other federal development.

Not all the total of these reserves is usable because some of it is reduced by conveyance losses and some of it consists of return flows that become part of the downstream reserve supply for a PSA. In addition, some of the reserve supply identified for a PSA may also be included in the amount identified for one or more other PSAs.

37. **Agricultural Flows to Salt Sinks**—Agricultural return flows that go to evaporation ponds, saline water bodies such as the Salton Sea or the ocean, or to saline ground water.

38. **Discharged to Saline Water**—Represents that portion of treated urban waste water discharged to saline surface and ground water bodies.

39. **Salinity Repulsion**—Fresh water outflow from the Sacramento-San Joaquin Delta to protect the beneficial uses within the Delta from the incursion of saline water.

40. **Wild and Scenic Rivers**—Average annual natural flows from the designated North Coast State and Federal Wild and Scenic Rivers systems.

41. **Remaining Runoff**—Represents the remaining natural runoff under average annual hydrologic conditions.

42. **Outflows to Nevada**—The average annual natural outflow to the State of Nevada.

SUMMARIES OF HYDROLOGIC STUDY AREAS

This section summarizes water-related information for the 12 Hydrologic Study Areas. Tables in this section present data on net water use and water supply. Irrigated and urban areas are depicted on the HSA maps, which also include tabulations of average precipitation, average natural runoff, irrigated land area, and population. Discussion sections include comments and highlights pertaining to population, water supply, and irrigated agriculture (significant changes in crops, irrigated land, and irrigation methods). Tabulations showing detailed hydrologic balances are included for the Los Angeles, Santa Ana, and San Diego HSAs (the South Coastal region) and the Sacramento, San Joaquin, and Tulare Lake HSAs (the Central Valley).

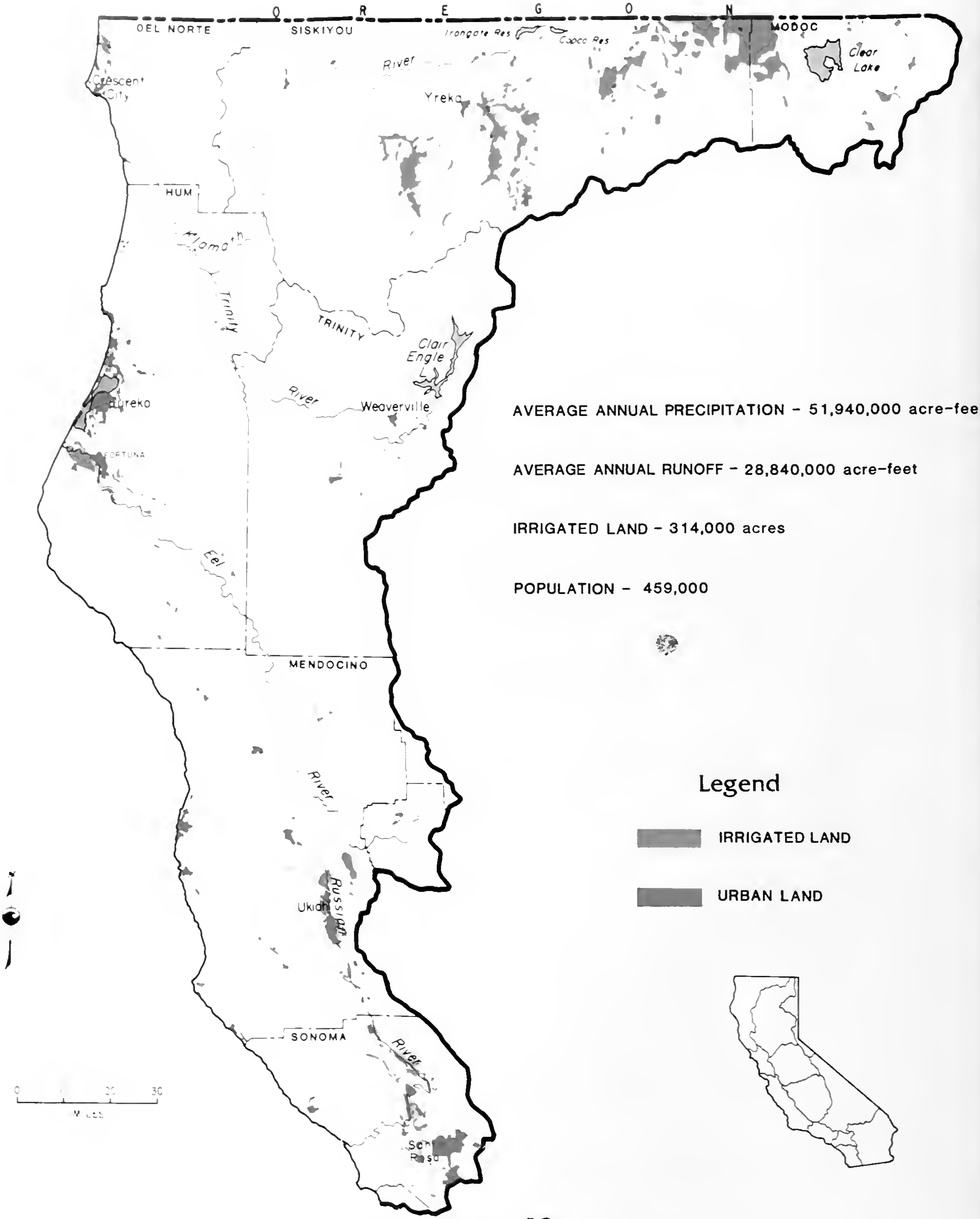


Figure 28.
NORTH COAST HYDROLOGIC STUDY AREA

NORTH COAST HYDROLOGIC STUDY AREA

Population

The Russian River portion of this area—the Santa Rosa area of Sonoma County, in particular—is undergoing the rapid growth that is characteristic of the San Francisco Bay metropolitan area. To preserve its agricultural industry, Sonoma County has passed an ordinance that bans the subdivision of farmlands into parcels of less than 20 acres.

Irrigated Agriculture

Irrigated lands in the North Coast HSA increased by 24,000 acres from 1972 to 1980 Changes included 18,000 acres of irrigated vineyards, both new and established, to which dual systems were added for frost protection (overhead spray) and irrigation (drip devices). Orchards, which have been replaced with vineyards, showed a decrease of 6,000 acres, while most other categories of crops showed a slight increase. Most of the newly irrigated land is supplied by ground water.

Russian River

The Russian River drainage basin in Mendocino and Sonoma Counties is noted for its orchards and varietal wine grape vineyards, a significant portion of which have been historically dry-farmed. The cropping pattern in this region has changed greatly since 1972, with urban encroachment and the replacement of many prune orchards by grape vineyards. In 1972, about 24,000 acres were planted to orchards; by 1980, orchards had declined to about 15,500 acres. In contrast, vineyards increased from about 33,000 acres in 1972 to about 36,700 acres in 1980. Also, irrigated vineyards, including those equipped with sprinklers primarily for frost protection, increased from 21,800 acres in 1972 to 27,400 acres in 1980. About 60 percent of the sprinkler-equipped acreages are actually irrigated during the summer; the remainder receive frost-control watering only. Most of the new vineyards planted in recent years are equipped with permanently set sprinkler systems, and some also have drip irrigation.

It is not uncommon in this region to see orchards under stress conditions because of insufficient soil moisture. Moisture stress severely reduces crop yield in some cases.

Remaining Areas

Irrigated acreage in the major agricultural areas draining into the Klamath River increased from 26,000 to 41,600 acres between 1969 and 1979. All the increase can be attributed to the development of ground water for irrigation, principally within Red Rock Valley and Butte Valley ground water basins. Red Rock Valley, an area with no irrigation in 1959, had 5,340 acres under irrigation in 1979. Irrigated agriculture within the Butte Valley ground water basin increased about 10,300 acres between 1969 and 1979. Alfalfa and grain are the irrigated crops that have shown the most substantial increases.

The long-standing method of wild flooding is still practiced in many counties of the Sierra Nevada and

TABLE 21

NET WATER USE AND WATER SUPPLY
NORTH COAST HYDROLOGIC STUDY AREA—1980
(In 1,000s of acre-feet)

Net Water Use		*Dependable Water Supply*	
Urban	151	Local surface water	368
		Major local imports	2
Irrigated agriculture	714	Ground water	243
		Central Valley Project	—
Energy production	—	Other federal projects	458
		State Water Project	—
Wildlife and recreation	216	Waste water reclamation	9
Conveyance losses	—	Use of dependable water supply	1,080
		Reserve supply	9
TOTAL	1,081	TOTAL DEVELOPED WATER	1,089

WATER BALANCE

Net Water Use	*Use of Dependable Water Supply*	*Use Met by Ground Water Overdraft*	*Urban Shortage*
1,081	1,080	—	1

the Cascade Range, including Siskiyou County. Typically, the system functions by diverting a stream into a ditch constructed to a slight grade that conveys water on a sloping contour along a hillside, eventually running above irrigable fields. Water is diverted from the ditch by flash boards, sand sacks, or other devices at intervals and allowed to flow onto and cover most of the field below. Although the system is a somewhat inefficient means of applying water, it is popular because it is inexpensive to establish and operate; also, it operates entirely by gravity. After the field is irrigated, excess water re-enters the local stream system and is again available for use on lower-lying fields. This results, however, in a greater reduction in streamflow between the point of diversion and the point of return to the stream than would occur in a more efficient system. Irrigated pasture is generally the only crop in this HSA irrigated in this manner.

SAN FRANCISCO BAY HYDROLOGIC STUDY AREA

Population

San Francisco County, the only county in California to lose population between 1970 and 1980, and San Jose, the fastest growing major city in the nation, are both in the San Francisco Bay HSA. Most of the growth that took place in the South Bay area was due to natural increase, rather than migration. However, growth in the South Bay is now being slowed by a scarcity of affordable housing. A survey by the Association of Bay Area Governments shows a decrease in housing densities in the suburbs since the change in property tax law in 1978 because counties have adopted fiscal zoning to require larger lots with higher values and thus increase their tax base. Completion of the Bay Area Rapid Transit in the early 1970s stimulated growth in the eastern counties of Solano and Contra Costa where more affordable housing existed. San Francisco Bay HSA's employment is heavily directed toward the aerospace and electronics industries. Santa Clara County ranks second in the State in numbers of people employed in the aerospace industry. The county is also the home of the electronics industry, which originated at Stanford University in the 1920s.

Irrigated Agriculture

The San Francisco Bay HSA, even with the pressure of urbanization, underwent a 1,000-acre net increase in irrigated area between 1972 and 1980. Irrigated vineyards increased by 16,000 acres. Among these were established, traditionally dry-farmed vineyards where irrigation had been added. Some of the new vineyards (as well as urban expansion) displaced irrigated orchards, which declined by 14,000 acres. Pasture declined by 8,000 acres and vegetables, by 1,000 acres. All other crops showed a slight increase. Most of the new irrigation relies on ground water.

South Bay Area

About 9,000 acres of irrigated crops remain in Santa Clara County. Water supplies are obtained by pumping ground water, which is recharged with about 35,000 acre-feet of State Water Project (SWP) water. About 3,000 acre-feet of recharged ground water is used for agricultural crop production. Intensive cultural practices maintain high irrigation efficiencies in the county—about 80 percent.

About 8,000 acres of irrigated crops are grown in the Livermore Valley (Zone 7 of the Alameda County Flood Control and Water Conservation District). Currently, the average irrigation efficiency is about 70 percent, and it is likely to increase further because of higher costs of energy for pumping ground water. The excess irrigation water enters the ground water basin underlying the Livermore Valley. About 2,000 acre-feet of irrigation water is obtained from the SWP and the remainder is ground water.

In the Alameda County Water District near Fremont and Newark, ground water is the source of all irrigation water. Major crops are cauliflower, lettuce, nursery stock, and flowers. The present irrigation efficiency (80 percent or greater in many cases) should continue about the same in the future.

The climate of the coastal area of San Mateo County is suitable for such specialty crops as Brussels sprouts, artichokes, and flowers. An inadequate supply of irrigation water is one of the main factors that restrains farming in this area. Underground water storage is limited; therefore, most of the water is obtained by pumping directly from creeks or by collecting winter runoff in small reservoirs for later use. Frequent coastal fogs help reduce the irrigation requirements in the area. Current irrigation efficiency is high, about 80 percent.

AVERAGE ANNUAL PRECIPITATION - 5,830,000 acre-feet

AVERAGE ANNUAL RUNOFF - 1,290,000 acre-feet

IRRIGATEDLAND - 64,000 acres

POPULATION - 4,790,000

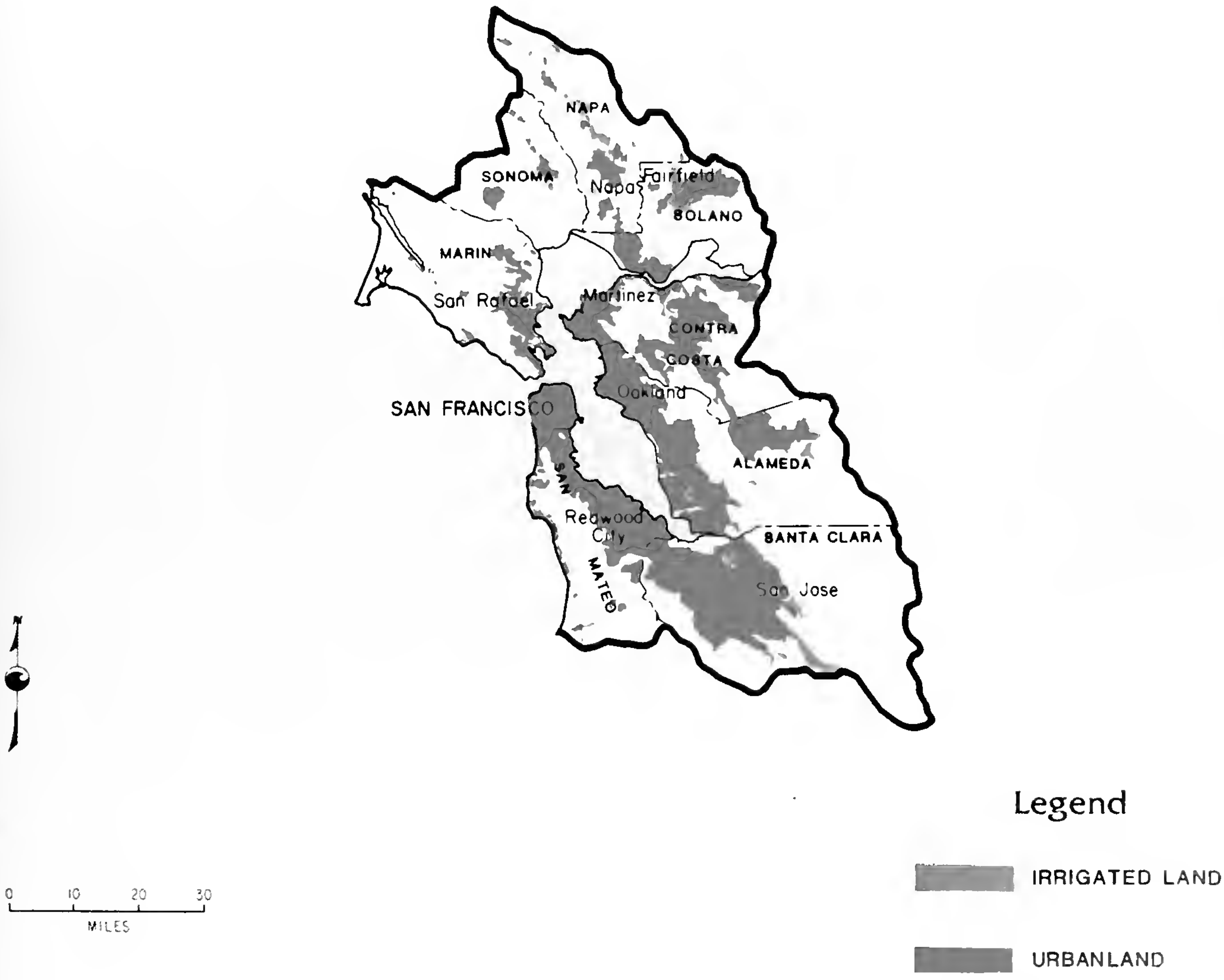


Figure 29.
SAN FRANCISCO BAY HYDROLOGIC STUDY AREA

TABLE 22

NET WATER USE AND WATER SUPPLY SAN FRANCISCO BAY HYDROLOGIC STUDY AREA—1980

(In 1,000s of acre-feet)

Net Water Use		Dependable Water Supply	
Urban	967	Local surface water	228
		Major local imports	454
Irrigated agriculture	121	Ground water	211
		Central Valley Project	81
Energy production	6	Other federal projects	56
		State Water Project	157[1]
Wildlife and recreation	96	Waste water reclamation	10
Conveyance losses	14	Use of dependable water supply	1,197
		Reserve supply	138
TOTAL	1,204	TOTAL DEVELOPED WATER	1,335

WATER BALANCE

Net Water Use	Use of Dependable Water Supply	Use Met by Ground Water Overdraft	Urban Shortage
1,204	1,197	7	—

[1] Includes SWP surplus water deliveries

North Bay Area

Vineyards are expanding into previously uncultivated hilly areas on the western and eastern fringes of the Napa Valley. They are irrigated mostly with drip systems, interspersed with sprinklers. Some growers use sprinklers for frost control only. Because water is in short supply in the Napa Valley, many growers maintain reservoirs to provide enough water to combat frost. The Napa River has been under a trial distribution program of the State Water Resources Control Board since 1973 to allocate river flows during the frost-risk season (March 15 to May 15).

In Napa County, about 95 percent of the irrigated crop acreage is vineyards. Irrigation efficiency is currently about 80 percent, with widespread use of sprinklers and drip systems. Sources of water are equally divided between surface and ground water.

In the North Bay portion of Solano County, about 68 percent of the irrigated crops consist of apricot, pear, prune, almond, and walnut orchards. Many orchards are now irrigated by the basin method. Pasture is irrigated by the border method. About 92 percent of the total crop acreage is irrigated with surface water, most of which is supplied by the Solano Project from water stored at Lake Berryessa.

CENTRAL COAST HYDROLOGIC STUDY AREA

Population

County growth from either migration or natural increase varied considerably within the Central Coast HSA. San Luis Obispo and Santa Cruz Counties' growth came from migration, 85 and 80 percent respectively, while 75 percent of the growth in Monterey County was due to natural increase. Government, trade, and services are the main employment industries.

Significant urban development occurred in San Luis Obispo and Santa Barbara Counties during the mid-1970s. The Santa Margarita-Paso Robles and San Luis Obispo-Pismo Beach areas and the Santa Maria and Lompoc Valleys experienced very noticeable urban growth. Increased aerospace research at Vandenberg Air Force Base was partially responsible for the urban expansion in the Santa Maria and Lompoc areas. Urban growth was severely limited in southern Santa Barbara County during much of the 1970s, due in large measure to the desires of the local citizens. Shortages of surface and ground water supplies and land limitations caused certain water agencies to restrict new housing construction.

Irrigated Agriculture

Irrigated land in the Central Coast HSA increased by 50,000 acres between 1972 and 1980. Expansion of vineyards accounted for 34,000 acres of this growth. Sprinklers are used for frost protection, irrigation, and high-temperature control, where needed. Orchards declined by 10,000 acres and were mostly replaced by vineyards. Irrigated grain increased by 5,000 acres; alfalfa, by 13,000 acres; and vegetables, by 50,000 acres. Pasture declined by 6,000 acres, and field crops declined by 4,000 acres.

San Luis Obispo and Santa Barbara Counties

Irrigated area has expanded in San Luis Obispo and Santa Barbara Counties. Much of the pasture has been converted to alfalfa. The area is supporting more irrigated small grains and truck crops. Field crop acreage in Santa Barbara County has been replaced by higher cash value truck crops, and citrus crops, or vineyards. Much of the truck crop acreage in Santa Barbara County is in nursery crops. Drip irrigation and low-pressure sprinklers have enabled farmers to plant citrus and avocado trees on steep lands. Large increases in vineyards have been the most recent noticeable change, along with more citrus fruit (mostly lemons) and avocados.

Urban encroachment has forced agriculture to move into marginal lands. Multiple cropping (more than one crop on the same parcel of land during the year) has become more prevalent in the Santa Maria and Lompoc Valleys.

The increased use of sprinkler and drip systems for irrigation in the southern part of the Central Coast

TABLE 23
NET WATER USE AND WATER SUPPLY
CENTRAL COAST HYDROLOGIC STUDY AREA—1980
(In 1,000s of acre-feet)

Net Water Use		*Dependable Water Supply*	
Urban	188	Local surface water	39
		Major local imports	—
Irrigated agriculture	902	Ground water	768
		Central Valley Project	—
Energy production	7	Other federal projects	54
		State Water Project	—
Wildlife and recreation	2	Waste water reclamation	9
Conveyance losses	—	Use of dependable water supply	870
		Reserve supply	17
TOTAL	1,099	TOTAL DEVELOPED WATER	887

WATER BALANCE

Net Water Use	*Use of Dependable Water Supply*	*Use Met by Ground Water Overdraft*	*Urban Shortage*
1,099	870	224	5

AVERAGE ANNUAL PRECIPITATION - 12,090,000 acre-feet

AVERAGE ANNUAL RUNOFF - 2,450,000 acre feet

IRRIGATED LAND - 459,000 acres

POPULATION - 1,005,000

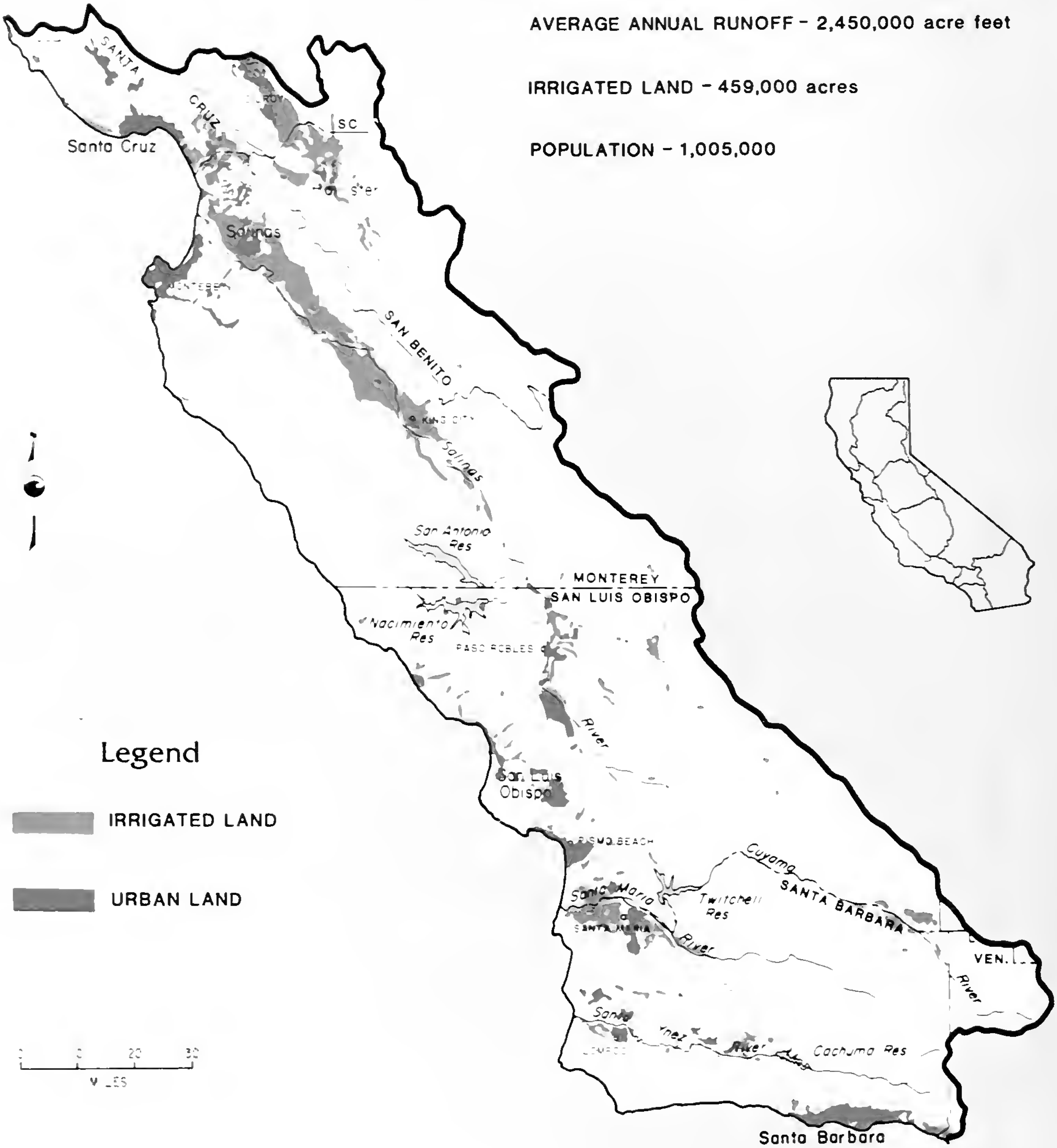


Figure 30.
CENTRAL COAST HYDROLOGIC STUDY AREA

1980

HSA represents attempts by farmers to increase on-farm efficiency and reduce water demand.

Salinas Valley

Nearly 20,000 acres of grapes have been planted in the Salinas Valley, where about half the plantings replace other irrigated crops and half occurred on new lands. Total truck crop planting in the Salinas Valley increased by 35,000 acres. This reflects an increase in multiple cropping, as well as an increase in irrigated lands. Broccoli, cauliflower, and lettuce were among the crops that gained. Sugar beet planting has decreased, and it will drop even more with the closing of the processing plant near Salinas.

San Benito County

Irrigated crop areas have increased by just over 10,000 acres, almost entirely in row crops. Among truck crops, tomatoes, broccoli, and onions showed substantial increases. Sugar beets was the field crop that increased the most, but acreages will probably decrease in the future with the closing of the processing plant near Salinas. Vineyards remained constant, and deciduous orchards continued to decrease.

Santa Clara Valley

About half the irrigated land in the Santa Clara Valley area is planted in truck crops, including cucumbers, lettuce, peppers, tomatoes, and other vegetables. Orchard crops include apricots, prunes, and walnuts. Ground water provides the primary irrigation water source. Irrigation efficiency is high, about 80 percent, with much of the irrigation done with sprinklers.

Santa Cruz County

Irrigated acreage did not exhibit much change. Deciduous orchards and field crops declined, but this was compensated for by an increase in vegetable crops.

AVERAGE ANNUAL PRECIPITATION - 4,440,000 acre-feet

AVERAGE ANNUAL RUNOFF - 580,000 acre-feet

IRRIGATED LAND - 118,000 acres

POPULATION - 7,927,000

Legend

IRRIGATED LAND

URBAN LAND

Figure 31.
LOS ANGELES HYDROLOGIC STUDY AREA

LOS ANGELES HYDROLOGIC STUDY AREA

Population

The Los Angeles HSA contains the Los Angeles-Long Beach standard metropolitan statistical area, the largest such area in California, and in the nation, both in terms of area and population.

The Los Angeles HSA has a strong economic base, with aerospace and service industries the dominant industrial activities. The area contains 40 percent of the State's aerospace industries, receives 70 percent of its foreign travelers, and houses Universal Studios, one of the ten leading visitor attractions in the United States. In recent years, 58 percent of the residential construction in this HSA was multiple-family units.

Irrigated Agriculture

Overall, the Los Angeles HSA shows a net loss of 2,000 acres of irrigated land since 1972 due to urban encroachment. In addition, double-cropped area declined by 3,000 acres.

Most of the irrigated land in this HSA is located in Ventura County, where both urban areas and agricultural irrigated acreage are expanding. Many farmers are planting avocado and citrus trees in foothills that were previously not irrigated. Other farmers are practicing more double-cropping, and some are even triple-cropping. Deciduous fruits and nuts and alfalfa are declining.

Higher energy and water costs, ground water quality problems, and possible water supply shortages are forcing farmers to improve their irrigation efficiencies. The use of sprinkler, drip, and low-flow sprinklers for seed germination and normal irrigation; the leveling of land to reduce irrigation runoff; and closer control of amounts of water applied are all examples of improved irrigation practices occurring in the area. New plantings of citrus and avocado trees are being irrigated with drip emitters and low-flow sprinklers, and older orchards are being converted to these newer systems.

Ground water overdraft in Ventura County has continued at about 70,000 acre-feet per year since 1970. This has caused identification of the Ventura County Ground Water Basin as subject to critical conditions of overdraft.

The dairy industry in the Chino-Ontario area of San Bernardino County has started to relocate into the San Jacinto Valley of Riverside County because of urban encroachment and environmental controls.

TABLE 24
NET WATER USE AND WATER SUPPLY
LOS ANGELES HYDROLOGIC STUDY AREA—1980
(In 1,000s of acre-feet)

Net Water Use		*Dependable Water Supply*	
Urban	1,534	Local surface water	29
		Major local imports	752
Irrigated agriculture	276	Ground water	483
		Central Valley Project	—
Energy production	7	Other federal projects	20
		State Water Project	481
Wildlife and recreation	8	Waste water reclamation	59
Conveyance losses	81	Use of dependable water supply	1,824
		Reserve supply	164
TOTAL	1,906	TOTAL DEVELOPED WATER	1,988

WATER BALANCE

Net Water Use	*Use of Dependable Water Supply*	*Use Met by Ground Water Overdraft*	*Urban Shortage*
1,906	1,824	82	—

DETAILED 1980 HYDROLOGIC BALANCES

The purpose of the following four tabulations is to provide a detailed analysis of the sources of water used (applied and net) in this HSA and to describe what happens to the water in the process of its use. The tabulations show the type of information displayed schematically for the entire State in Figure 27. Applied water totals in these tabulations do not necessarily agree with totals in Table 16 because such items as artificial recharge are counted as applied water to show in more detail the complex interrelationship between supply and use.

DETAILED 1980 HYDROLOGIC BALANCES—LOS ANGELES HSA
(in 1,000s of acre-feet)

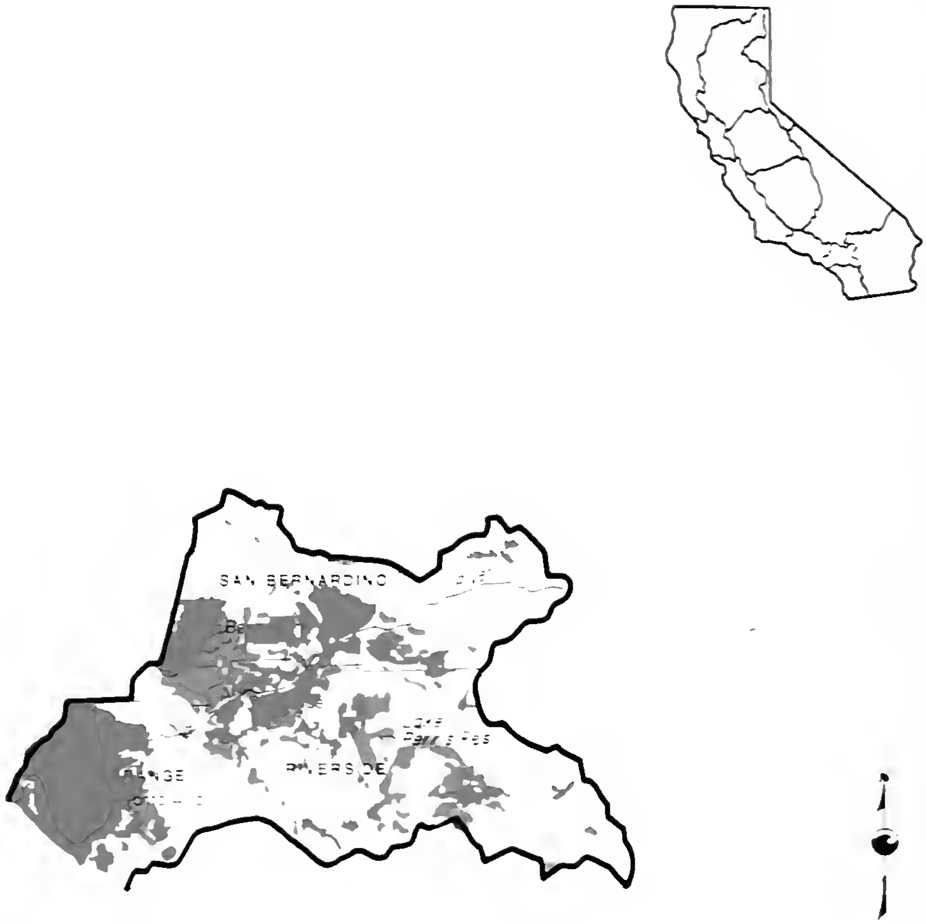
SOURCES OF APPLIED WATER	
Surface Water	
Local	29
Federal	20
Imports: Los Angeles Aqueduct	
Mono Basin	98
Owens Valley	369
Colorado River	242
SWP	443
Waste Water Reclamation	59
Subtotal	1,260
Ground Water	
Prime Supply	
Natural Recharge	263
Artificial Recharge of Local Surface Supplies	220
Artificial Recharge	
Planned Reclamation	22
Imported Surface Supplies	150
Sea-water Intrusion Barrier	43
Deep Percolation from:	
Urban Use	103
Agricultural Use	72
Incidental Reclamation	17
Withdrawal from Ground Water Storage	82
Subtotal	972
TOTAL	2,232

APPLIED WATER DISBURSEMENT	
Urban Use	
ETAW	472
Incidental Reclamation	17
Planned Reclamation	59
Flows to Salt Sinks	1,001
Deep Percolation	103
Subtotal	1,652
Agricultural Use	
ETAW	217
Flows to Salt Sinks	59
Deep Percolation	72
Subtotal	348
Other Use	
Wildlife	
ETAW	4
Flows to Salt Sinks	3
Recreation	1
Energy Production	
ETAW	5
Flows to Salt Sinks	2
Subtotal	15
Artificial Recharge	
Reclaimed Water	22
Imported Surface Supplies	150
Sea-water Intrusion Barrier	43
Salinity Repulsion	2
Subtotal	217
TOTAL	2,232

Los Angeles HSA (Continued)

NET WATER SUPPLY	
Local	29
Federal (non-CVP)	20
Mono Basin	100
Owens Valley	382
Colorado River	270
SWP	481
Waste Water Reclamation	59
Ground Water Prime Supply	483
TOTAL DEPENDABLE SUPPLY	1,824
Withdrawal from Ground Water Storage	82
TOTAL NET SUPPLY	1,906

NET WATER USE	
Urban Use	
ETAW	472
Flows to Salt Sinks	1,001
Planned Reclamation	59
Artificial Recharge for Salinity Repulsion	2
Subtotal	1,534
Agricultural Use	
ETAW	217
Flows to Salt Sinks	59
Subtotal	276
Other Use	
Wildlife	7
Recreation	1
Energy Production:	
ETAW	5
Flows to Salt Sinks	2
Subtotal	15
Conveyance Loss	
Mono Basin	2
Owens Valley	15
Colorado River	28
SWP	38
Subtotal	81
TOTAL	1,906



Legend

IRRIGATED LAND

URBAN LAND

0 10 20 30
MILES

AVERAGE ANNUAL PRECIPITATION - 2,550,000 acre-feet

AVERAGE ANNUAL RUNOFF - 310,000 acre-feet

IRRIGATED LAND - 147,000 acres

POPULATION - 2,974,000

Figure 32.
SANTA ANA HYDROLOGIC STUDY AREA

SANTA ANA HYDROLOGIC STUDY AREA

Population

The Santa Ana HSA incorporates portions of Orange, Riverside, and San Bernardino Counties. Population gains in Orange County result from suburban development due to rapid employment growth of the Los Angeles metropolitan area. Aerospace, electronics, and service (tourism) industries provide the economic base. Two of the ten leading visitor attractions in the United States—Disneyland and Knott's Berry Farm—are located in Orange County.

As a result of rapid urbanization, and other economic forces, the price of the average home has soared, forcing many people to seek more affordable housing in Riverside and San Bernardino Counties. San Bernardino's favorable location for warehousing and distribution has led to a concentration of many freight carriers. From 1972 to 1980, migration accounted for approximately 75 percent of the growth in the Santa Ana HSA.

Irrigated Agriculture

Irrigated agriculture in the Santa Ana HSA declined by 38,000 acres between 1972 and 1980. All crop categories show a loss, primarily due to urban expansion, especially in Orange County. Some of the reduction has been offset through the relocation of agriculture into hillside areas not previously irrigated. New plantings of avocado and citrus trees and vineyards have occurred on these hillsides, although development costs have been high and special irrigation techniques are needed, such as low-flow sprinklers and drip systems.

TABLE 25

NET WATER USE AND WATER SUPPLY
SANTA ANA HYDROLOGIC STUDY AREA—1980
(In 1,000s of acre-feet)

Net Water Use		*Dependable Water Supply*	
Urban	586	Local surface water	93
		Major local imports	290
Irrigated agriculture	320	Ground water	402
		Central Valley Project	—
Energy production	9	Other federal projects	—
		State Water Project	138
Wildlife and recreation	2	Waste water reclamation	29
Conveyance losses	45	Use of dependable water supply	952
		Reserve supply	203
TOTAL	962	TOTAL DEVELOPED WATER	1,155

WATER BALANCE

Net Water Use	*Use of Dependable Water Supply*	*Use Met by Ground Water Overdraft*	*Urban Shortage*
962	952	10	—

DETAILED 1980 HYDROLOGIC BALANCES

The purpose of the following four tabulations is to provide a detailed analysis of the sources of water used (applied and net) in this HSA and to describe what happens to the water in the process of its use. The tabulations show the type of information displayed schematically for the entire State in Figure 27. Applied water totals in these tabulations do not necessarily agree with totals in Table 16 because such items as artificial recharge are counted as applied water to show in more detail the complex interrelationship between supply and use.

DETAILED 1980 HYDROLOGIC BALANCES—SANTA ANA HSA
(In 1,000s of acre-feet)

SOURCES OF APPLIED WATER	
Surface Water	
Local	93
Imports: Colorado River	273
SWP	110
Waste Water Reclamation	29
Subtotal	505
Ground Water	
Prime Supply:	
Natural Recharge	278
Artificial Recharge of Local Surface Supplies	124
Artificial Recharge:	
Planned Reclamation	1
Imported Surface Supplies	118
Sea-water Intrusion Barrier	2
Deep Percolation from:	
Urban Use	74
Agricultural Use	92
Incidental Reclamation	74
Withdrawal from Ground Water Storage	10
Subtotal	773
TOTAL	1,278

APPLIED WATER DISBURSEMENT	
Urban Use	
ETAW	170
Incidental Reclamation	74
Planned Reclamation	29
Flows to Salt Sinks	383
Deep Percolation	74
Subtotal	730
Agricultural Use	
ETAW	252
Flows to Salt Sinks	92
Deep Percolation	68
Subtotal	412
Other Use	
Recreation	2
Energy Production:	
ETAW	8
Flows to Salt Sinks	1
Subtotal	11
Artificial Recharge	
Reclaimed Water	1
Imported Surface Supplies	118
Sea-water Intrusion Barrier	2
Salinity Repulsion	4
Subtotal	125
TOTAL	1,278

Santa Ana HSA (Continued)

NET WATER SUPPLY	
Local	93
Colorado River	290
SWP	138
Waste Water Reclamation	29
Ground Water Prime Supply	402
TOTAL DEPENDABLE SUPPLY	952
Withdrawal from Ground Water Storage	10
TOTAL NET SUPPLY	962

NET WATER USE	
Urban Use	
ETAW	170
Flows to Salt Sinks	383
Planned Reclamation	29
Artificial Recharge for Salinity Repulsion	4
Subtotal	586
Agricultural Use	
ETAW	252
Flows to Salt Sinks	68
Subtotal	320
Other Use	
Recreation	2
Energy Production:	
ETAW	8
Flows to Salt Sinks	1
Subtotal	11
Conveyance Loss	
Colorado River	17
SWP	28
Subtotal	45
TOTAL	962

AVERAGE ANNUAL PRECIPITATION - 3,770,000 acre-feet

AVERAGE ANNUAL RUNOFF - 330,000 acre-feet

IRRIGATED LAND - 100,000 acres

POPULATION - 2,068,000

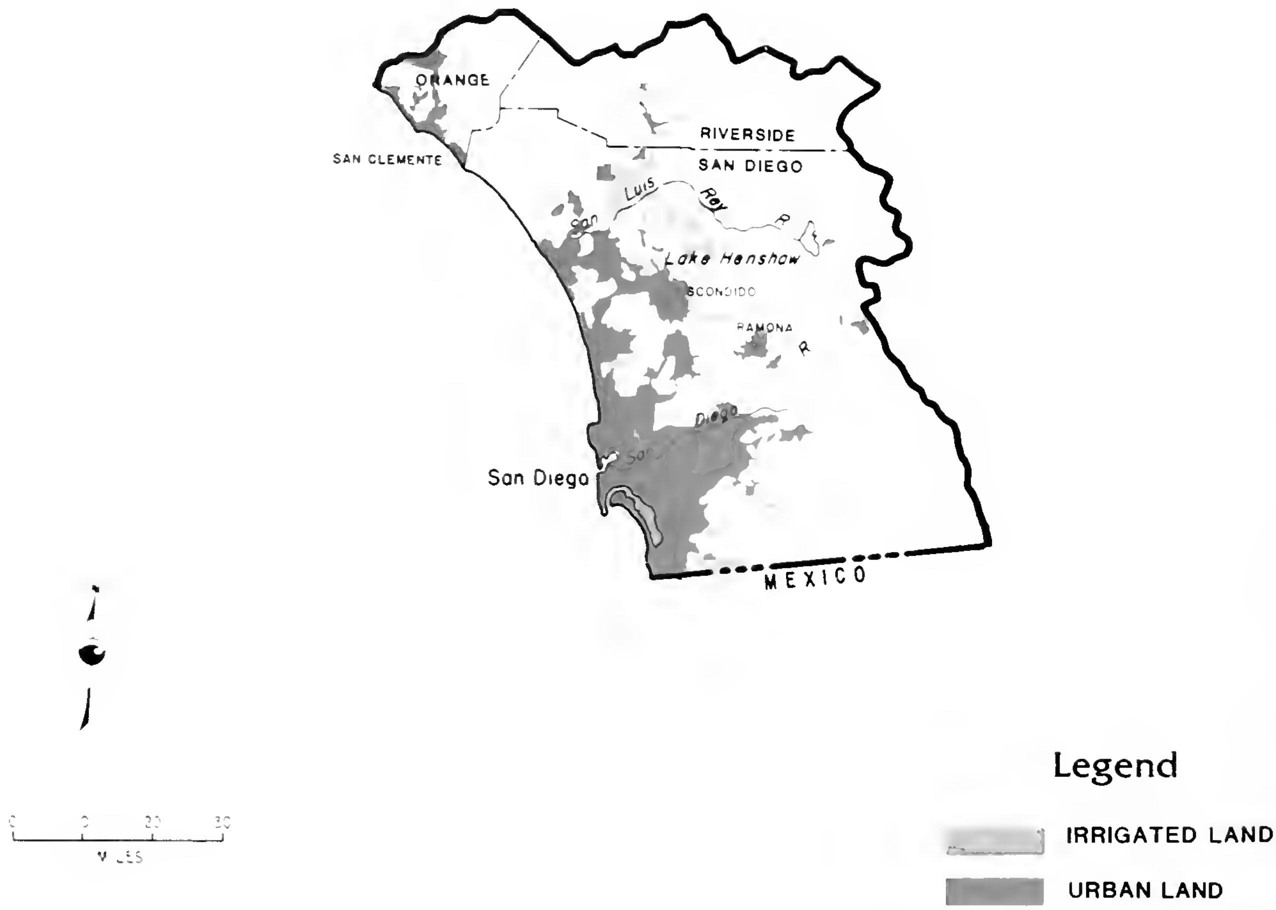


Figure 33.
SAN DIEGO HYDROLOGIC STUDY AREA

SAN DIEGO HYDROLOGIC STUDY AREA

Population

Growth in the San Diego HSA has been occurring in the suburbs. Migration has accounted for about three-fourths of this growth, and about 75 percent of the new residents came from outside the State. Employment in the city of San Diego is concentrated in the aerospace, electronics, government (military), and service (tourism) industries. The San Diego Zoo is the fourth most popular of the ten leading visitor attractions in the United States. Half the residential construction in this HSA was multiple-family units. This was the second highest such proportion in the State.

Irrigated Agriculture

Irrigated area in the San Diego HSA experienced a net increase of 12,000 acres between 1972 and 1980, despite the pressure of urban spread. Avocado, citrus, and grain acreages all increased, with avocado and citrus together showing a 20,000-acre increase and irrigated grain, a 6,000-acre increase. Pasture and truck crop acreages each declined by about 10,000 acres. All other crops remained stable.

Urban growth has been extensive in this area, while new orchards have been established on rough and steep hillsides, irrigated with drip systems.

In recent years, irrigation of most of its older citrus and avocado trees has been converted to drip and low-flow sprinkler systems because of the high price of imported water. These systems have also been used to irrigate some truck and field crops. Furrow irrigation systems are also still in use, although closer attention is being given to management.

TABLE 26

NET WATER USE AND WATER SUPPLY
SAN DIEGO HYDROLOGIC STUDY AREA—1980
(In 1,000s of acre-feet)

Net Water Use		*Dependable Water Supply*	
Urban	389	Local surface water	37
		Major local imports	290
Irrigated agriculture	198	Ground water	77
		Central Valley Project	—
Energy production	—	Other federal projects	—
		State Water Project	221
Wildlife and recreation	7	Waste water reclamation	9
Conveyance losses	40	Use of dependable water supply	634
		Reserve supply	46
TOTAL	634	TOTAL DEVELOPED WATER	680

WATER BALANCE

Net Water Use	*Use of Dependable Water Supply*	*Use Met by Ground Water Overdraft*	*Urban Shortage*
634	634	—	—

DETAILED 1980 HYDROLOGIC BALANCES

The purpose of the following four tabulations is to provide a detailed analysis of the sources of water used (applied and net) in this HSA and to describe what happens to the water in the process of its use. The tabulations show the type of information displayed schematically for the entire State in Figure 27. Applied water totals in these tabulations do not necessarily agree with totals in Table 16 because such items as artificial recharge are counted as applied water to show in more detail the complex interrelationship between supply and use.

DETAILED 1980 HYDROLOGIC BALANCES—SAN DIEGO HSA
(In 1,000s of acre-feet)

SOURCES OF APPLIED WATER

Surface Water	
Local	37
Imports: Colorado River	273
SWP	198
Waste Water Reclamation	9
Subtotal	517
Ground Water	
Prime Supply	77
Artificial Recharge:	
Planned Reclamation	1
Imported Surface Supplies	50
Deep Percolation from:	
Agricultural Use	30
Subtotal	158
TOTAL	675

APPLIED WATER DISBURSEMENT

Urban Use	
ETAW	105
Planned Reclamation	9
Flows to Salt Sinks	275
Subtotal	389
Agricultural Use	
ETAW	146
Flows to Salt Sinks	52
Deep Percolation	30
Subtotal	228
Other Use	
Recreation	2
Wildlife	5
Subtotal	7
Artificial Recharge	
Reclaimed Water	1
Imported Surface Supplies	50
Subtotal	51
TOTAL	675

NET WATER SUPPLY

Colorado River	290
SWP	221
Waste Water Reclamation	9
Ground Water Natural Recharge	77
TOTAL DEPENDABLE SUPPLY	634

NET WATER USE

Urban Use	
ETAW	105
Flows to Salt Sinks	275
Planned Reclamation	9
Subtotal	389
Agricultural Use	
ETAW	146
Flows to Salt Sinks	52
Subtotal	198
Other Use	
Recreation	2
Wildlife	5
Subtotal	7
Conveyance Loss	
Colorado River	17
SWP	23
Subtotal	40
TOTAL	634

SACRAMENTO HYDROLOGIC STUDY AREA

Population

Most of the people migrating into the Sacramento HSA come from the metropolitan areas of Los Angeles, San Diego, and San Francisco. For many, their reasons for relocating include lower home prices, less congestion, better air quality, and closeness to rural and mountain areas. El Dorado County, for instance, owes 90 percent of its growth to immigration. The Sacramento HSA also has an abundant supply of reasonably priced industrial and commercial property which is attracting new industry and business. Government employment opportunities are also important. Currently, 30 percent of the jobs in State government exist in Sacramento, Placer, and Yolo Counties.

Irrigated Agriculture

The Sacramento HSA underwent an increase of 354,000 acres of irrigated land between 1972 and 1980. In addition, double-cropping increased by 73,000 acres. Two crops are primarily responsible for this large change. Irrigated grain (320,000 acres), primarily wheat, replaced dry-farmed grain, primarily barley. The second crop, rice, increased by 178,000 acres. This was brought about by the increased world demand, coupled with new varieties that produced greater yields, which has meant greater dollar returns per acre (see the sidebar, "The Sacramento Valley Rice Bonanza" earlier in this chapter). Alfalfa and pasture declined by 44,000 and 76,000 acres, respectively, while orchard acreage remained stable. Vegetable production increased by 31,000 acres, mostly in melons and tomatoes. The double-cropping pattern practiced in the area is small grains, followed by field corn (for silage), milo, dry beans, melons, or squash.

Sacramento Valley Floor Area

The water for increased irrigation was supplied by the Tehama-Colusa Canal, increased use of other surface supplies, and ground water. Irrigated agriculture in the Sacramento Valley has developed mainly by the appropriation of gravity-flow water supplies for large irrigation districts and, to a lesser extent, by individual diverters who exercise riparian water rights. Surface water costs in the Sacramento Valley are very low, generally averaging $5 to $7 per acre-foot or even less. Approximately 30 percent of the

TABLE 27
NET WATER USE AND WATER SUPPLY
SACRAMENTO HYDROLOGIC STUDY AREA—1980
(In 1,000s of acre-feet)

Net Water Use		*Dependable Water Supply*	
Urban	493	Local surface water	2,866
		Major local imports	9
Irrigated agriculture	6,682	Ground water	1,798
		Central Valley Project	2,422
Energy production	—	Other federal projects	259
		State Water Project	—
Wildlife and recreation	160	Waste water reclamation	17
Conveyance losses	129	Use of dependable water supply	7,371
		Reserve supply	535
TOTAL	7,464	TOTAL DEVELOPED WATER	7,906

WATER BALANCE

Net Water Use	*Use of Dependable Water Supply*	*Use Met by Ground Water Overdraft*	*Urban Shortage*
7,464	7,371	85	8

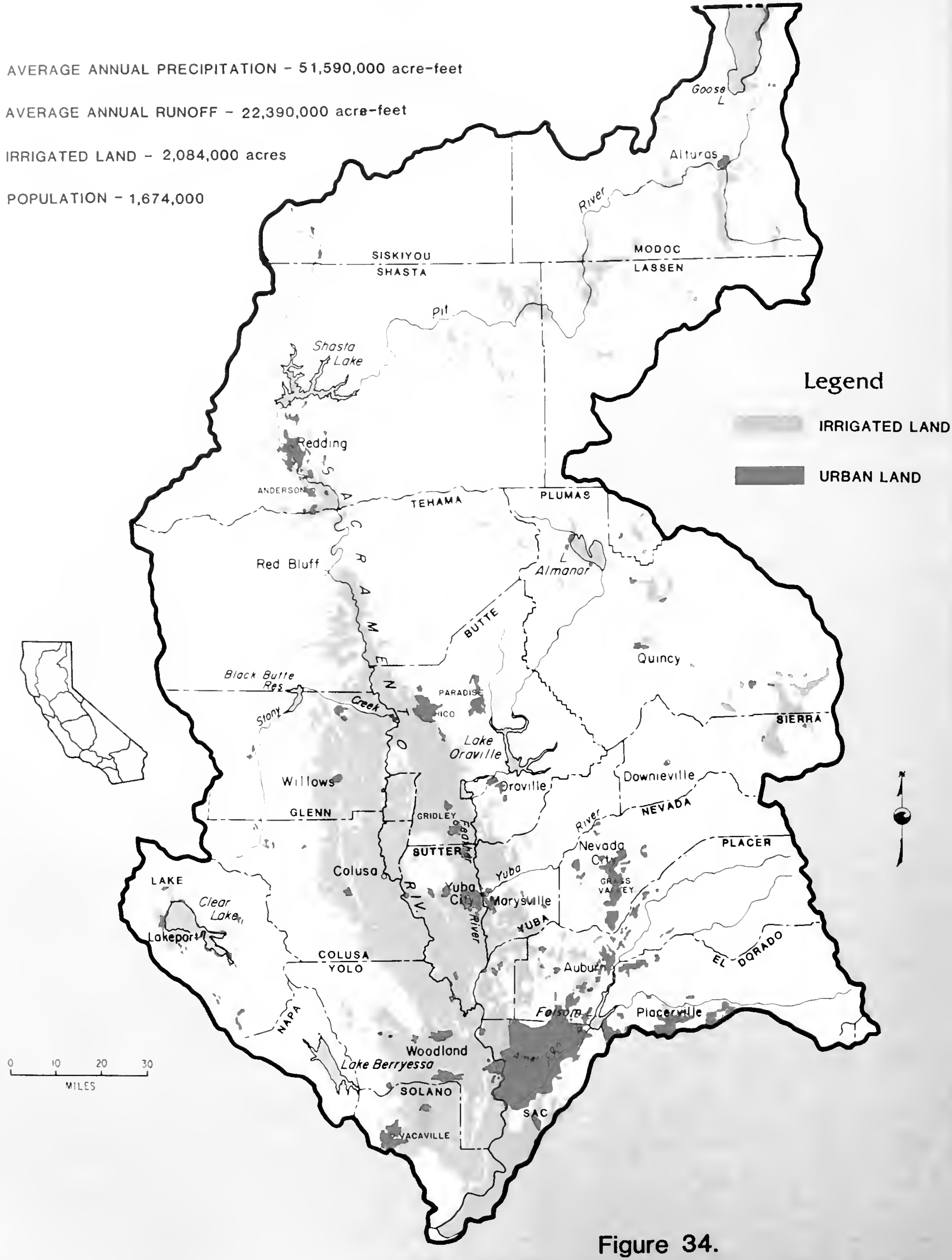


Figure 34.
SACRAMENTO HYDROLOGIC STUDY AREA

water used today is derived from ground water. Escalation of costs for well drilling and energy for pumping has increased the cost of ground water to over $10 per acre-foot in many areas. Most ground water is currently applied to orchard lands where on-farm irrigation efficiencies are high, approaching 70 percent.

Growers in western Yolo County are beginning to replace dry-farmed grain with irrigated grain and bean crops, using large wheel-line and center-pivot sprinkler systems.

Butte County growers are using both drip and sprinkler systems to grow kiwi fruit. Drip is used principally for irrigation, while most sprinkler systems are employed for frost protection.

In 1980, small grains and corn accounted for about half the irrigated acreage in the Sacramento HSA portion of the Sacramento-San Joaquin Delta. Other important crops, in numbers of acres, are tomatoes, safflower, sugar beets, and pasture. This part of the Delta is one of the few areas in the State that grows Bartlett pears, and, in recent years, the culture of quality wine grapes has come into prominence.

Precision land leveling, now commonly used, has greatly aided in maintaining desired water levels in rice culture. Traditionally, rice farmers have irrigated rice by turning on the headgate in early May, allowing the water to flow continuously through the rice paddy and spill into drains at the end of the field. Applied water of 9 to 10 acre-feet per acre or even higher were common. It has been demonstrated that rice can be grown with 6 or fewer acre-feet per acre of applied water where soils are sufficiently impervious and the paddies can be leveled accurately enough to enable close control of water. Rice probably will always be flood-irrigated, but application rates should continue to decline as varieties with shorter growing seasons are developed and some of the recently developed irrigation practices become more common.

Mountains and Valleys of the Northeast Area

Agriculture in the Pit River drainage area underwent some significant changes between 1972 and 1980, with the greatest change taking place within the most recent years. After a long period of unchanging agricultural activity, irrigated acreage increased from 48,100 to 53,000 acres. Most of the increase was due to the planting of alfalfa and grain. The cropping pattern also changed on the older irrigated land. Alfalfa and grain replaced pasture on some of the deeper, well-drained soils. Sprinkler irrigation was used only to a limited extent in 1972, primarily to irrigate some alfalfa and grain; this has increased greatly in recent years. The trend of conversion from flood to sprinkler irrigation is continuing. Sprinklers are being used on all areas recently developed for irrigation using ground water. The center pivot's labor-saving features are important to the farmer in this labor-short area. Wheel-line sprinkler irrigation systems have also become common.

The Dorris Lake area southeast of Alturas and the area north of Alturas along State Highway 395 as far as the shore of Goose Lake produce high yields of good quality ground water. Most of the wells have been drilled in known alluvial basins. There is a great uncertainty involved in drilling wells in volcanic rock. Success or failure depends entirely on encountering fractures or interconnected spaces in the rock that contain a sufficient quantity of water to supply a well continuously.

Reserve Water Supply

The 535,000 acre-feet of "reserve supply" in this HSA is principally Central Valley Project yield for which neither conveyance systems have been completed nor contracts been signed with water users.

DETAILED 1980 HYDROLOGIC BALANCES

The purpose of the following four tabulations is to provide a detailed analysis of the sources of water used (applied and net) in this HSA and to describe what happens to the water in the process of its use. The tabulations show the type of information displayed schematically for the entire State in Figure 27. Applied water totals in these tabulations do not necessarily agree with totals in Table 16 because such items as artificial recharge are counted as applied water to show in more detail the complex interrelationship between supply and use.

The net water supply and net water use tabulations are based on information developed for each subarea of the HSA. Therefore, in some cases, the values given for return flows sometimes include outflows from one subarea that become part of the water supply to downstream subareas within the HSA. A balance is obtained by including these quantities in the value given for local surface water supply. The sum of these return flows is shown as "Return Flow to Downstream Area in HSA."

DETAILED 1980 HYDROLOGIC BALANCES—SACRAMENTO HSA
(In 1,000s of acre-feet)

SOURCES OF APPLIED WATER	
Surface Water	
Local	2,835
Imports by Locals	9
CVP	2,324
Other Federal (non-CVP)	259
Waste Water Reclamation	17
Subtotal	5,444
Local Conveyance Loss to Ground Water	−45
Surface Reuse	
Urban	77
Agriculture	2,074
Wildlife	10
Subtotal	7,560
Ground Water	
Prime Supply	1,798
Local Conveyance Loss	45
Deep Percolation from Agricultural Use	467
Withdrawal from Ground Water Storage	85
Subtotal	2,395
TOTAL	9,955

APPLIED WATER DISBURSEMENT	
Urban Use	
ETAW	195
Waste Water Reclamation	17
Return Flow to Delta	161
Return Flow to Downstream Areas in HSA	54
Other Losses	66
Reuse—Surface Water	77
Subtotal	570
Agricultural Use	
ETAW	4,921
Return Flow to Delta	530
Return Flow to Downstream Areas in HSA	680
Riparian and Distribution System ET	551
Reuse—Surface Water	2,074
Reuse—Ground Water	467
Subtotal	9,223
Other Use	
Wildlife ETAW:	
from Applied Water	112
from Conveyance Loss	45
Reuse—Surface Water	10
Recreation	3
Subtotal	170
Total Need for Applied Water	9,963
Reduction in Use Due to Shortage	−8
TOTAL	9,955

Sacramento HSA (Continued)

NET WATER SUPPLY

Local Surface	2,866
Imports by Locals	9
CVP	2,422
Other Federal (non-CVP)	259
Waste Water Reclamation	17
Ground Water Prime Supply	1,798
TOTAL DEPENDABLE SUPPLY	7,371
Withdrawal from Ground Water Storage	85
TOTAL NET SUPPLY	7,456
Spillage to Downstream Areas in HSA (Local Conveyance Loss)	-77
Return Flow to Downstream Areas in HSA	-734
Return Flow to Delta	-691
TOTAL SUPPLY AVAILABLE FOR DEPLETIONS	5,954

NET WATER USE

Urban Use	
ETAW	195
Waste Water Reclamation	17
Return Flow to Downstream Areas in HSA	54
Return Flow to Delta	161
Other Losses	66
Subtotal	493
Agricultural Use	
ETAW	4,921
Return Flow to Downstream Areas in HSA	680
Return Flow to Delta	530
Riparian and Distribution System ET	551
Subtotal	6,682
Other Use	
Wildlife ETAW	
from Applied Water	112
from Conveyance Losses	45
Recreation	3
Other Conveyance Losses	
Spillage to Downstream Areas in HSA	77
Evaporation and ET	52
Subtotal	289
TOTAL NET USE	7,464
Reduction in Use Due to Shortage	-8
Spillage and Return Flow to Downstream Areas in HSA	-811
Return Flow to Delta	-691
TOTAL DEPLETIONS	5,954

AVERAGE ANNUAL PRECIPITATION - 22,950 000 acre-feet

AVERAGE ANNUAL RUNOFF - 7,930,000 acre-feet

IRRIGATED LAND - 2,062,000 acres

POPULATION - 1,014,000

Legend

IRRIGATED LAND

URBAN LAND

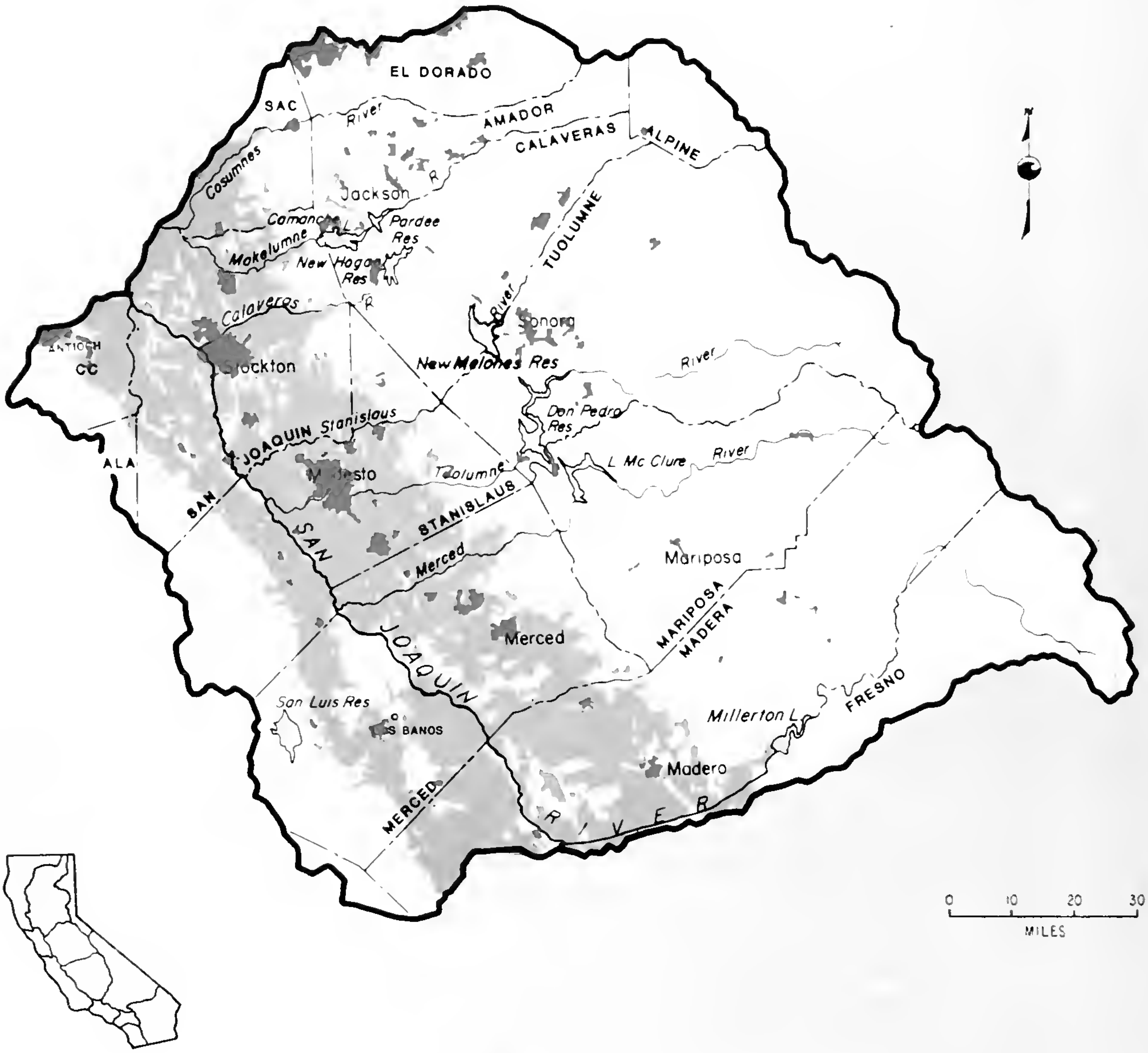


Figure 35.
SAN JOAQUIN HYDROLOGIC STUDY AREA

SAN JOAQUIN HYDROLOGIC STUDY AREA

Population

Population growth in the various parts of the San Joaquin HSA has either equalled or exceeded substantially the State's overall growth rate of 15 percent. The city of Stockton, for example, grew 36 percent from 1970 to 1980. The increase is attributable to reasonably priced land, labor, and housing. Housing construction remains predominantly single-family dwellings. Agriculture and government are the principal employers.

Irrigated Agriculture

Gross value of agricultural production in the San Joaquin HSA was about $2.9 billion in 1980, nearly triple the 1972 value, and more than one-fifth of the State's total. Merced, San Joaquin, and Stanislaus Counties ranked fourth, fifth, and eighth in gross value of agricultural production among the counties of the State in 1980.

A large amount of new irrigated land has been put into production since 1972; however, the net increase was only 33,000 acres, because of considerable urban growth that occurred on formerly irrigated crop land. The cities of Stockton and Modesto were the most notable examples of urban encroachment.

Areas of increase in agricultural irrigation are located principally along the San Joaquin River, where alkali lands were reclaimed and planted to field crops, and along the east side of the valley on hardpan terraces and in rolling foothills. The hardpan was broken up with special heavy equipment (rippers) and, along with the foothill areas, was planted to almonds, wine grapes, and, in eastern Madera County, additional pistachio nut trees. Both the reclamation of alkali land and the movement of irrigation into the eastern foothills continues trends that were evident in 1972.

In addition to development of new land, changes took place in the relative proportion of crops on previously developed land. The largest increases occurred in almonds, wine grapes, small grains, and cotton. There was a rather large decrease in irrigated pasture and alfalfa.

The Delta

In the 1950s, asparagus was the major crop in the Sacramento-San Joaquin Delta, with about 80,000 acres harvested annually. But, with the loss of the European market to Taiwan and labor problems in

TABLE 28

NET WATER USE AND WATER SUPPLY
SAN JOAQUIN HYDROLOGIC STUDY AREA—1980
(In 1,000s of acre-feet)

Net Water Use		*Dependable Water Supply*	
Urban	249	Local surface water	3,055
		Major local imports	—
Irrigated agriculture	5,892	Ground water	972
		Central Valley Project	1,838
Energy production	15	Other federal projects	55
		State Water Project	8
Wildlife and recreation	74	Waste water reclamation	21
Conveyance losses	111	Use of dependable water supply	5,949
		Reserve supply	191
TOTAL	6,341	TOTAL DEVELOPED WATER	6,140

WATER BALANCE

Net Water Use	*Use of Dependable Water Supply*	*Use Met by Ground Water Overdraft*	*Urban Shortage*
6,341	5,949	391	1

the early 1960s, asparagus declined until, in 1980, fewer than 20,000 acres of asparagus were harvested. Field corn is the predominant crop in the Delta today.

Amador County

In Amador County, small family-size vineyards (10 to 300 acres) are being established. This activity is centered in the Shenandoah Valley. Currently, the county has 13 wineries, and more are in the planning stage. About 1,500 acres are planted to vineyards; about half are irrigated. An additional 2,000 acres of land at the 1,000-to-2,000-foot elevation have available water and suitable climate and soil characteristics for grapes.

Folsom South Canal Service Area

About 60 percent of the agricultural land in the Folsom South Canal service area is irrigated. About 25 percent of this irrigated area is planted in pasture; 25 percent, in field crops; 25 percent, in fruit and nuts and vineyard; 10 percent, in grain; and 15 percent, in rice, alfalfa, and truck crops. The remainder is dry-farmed grain or used for dry-land pasture which is gradually being developed for irrigated agriculture. Much of the dry-land pasture, however, is expected to remain in its present use as open grasslands.

Generally speaking, soils of the Folsom South Canal service area are either older terrace hardpan or recent alluvial floodplain soils. The hardpan soils, which occupy most of the area, are limited to growing shallow-rooted crops such as pasture and grain. The floodplain soils are relatively deep and suitable for a wide range of crops, including orchard, vineyard, and row crops. Considerable urban encroachment has occurred on lands suitable for agriculture near Sacramento, Stockton, and Lodi.

Eastern Stanislaus and Merced Counties

In the Montpelier area in eastern Stanislaus and Merced Counties, between the Merced and Tuolumne Rivers, about 10,000 acres were developed for irrigation between 1972 and 1980, all with ground water. The soils in this area are predominantly gently rolling high terrace or upland soils with hardpan or substrata that restricts rooting depths. Growers have altered these into highly productive soils by ripping them. Almonds are the predominant crop. There are also large plantings of wine grapes.

The highest field corn yield in the notion often occurs in the Deltc.

Water Supply

Surface Water Supply

The amount of surface storage for regulation of local streamflow has increased significantly in recent years, as indicated in the following table.

Dam	Gross Storage Capacity (In acre-feet) Original Construction	Enlargement	Year Enlargement Completed
Exchequer	289,000	1,026,000	1967
Don Pedro	289,000	2,030,000	1971
Melones	112,500	2,400,000	1979
TOTAL	690,500	5,456,000	

In addition, new dams have been constructed on the Chowchilla River (Buchanan) and Fresno River (Hidden) with gross capacities of 150,000 and 90,000 acre-feet, respectively. This additional storage has increased operational flexibility and provided long-term carryover storage (as well as seasonal carryover), thereby firming up water supplies and increasing production of energy. Operations studies by the U.S. Army Corps of Engineers indicate that the Hidden and Buchanan projects each provide a 24,000-acre-foot annual new water supply.

Ground Water Overdraft

Ground water overdraft (currently about 390,000 acre-feet) has developed in the San Joaquin HSA, principally in the area east of the San Joaquin River and north of the Chowchilla River outside the boundaries of organized water agencies. A smaller overdrafted area has also developed in an area between the Tuolumne and Merced Rivers outside the boundaries of organized water agencies.

Land use surveys made by the Department of Water Resources in Stanislaus, Merced, and Madera Counties indicate that, between 1958 and 1975, irrigated lands on the valley floor increased by 210,000 acres and 80 percent of this increase occurred on lands in which surface deliveries accounted for only about 15 percent of the applied water. The remaining 85 percent of applied water was derived from ground water pumping.

Ground Water Pumping Lifts and Costs

Ground water pumping lifts range from a minimum of 15 feet near the confluence of the Merced and San Joaquin Rivers to over 200 feet in the uplands area east of the city of Madera. The average pumping lift was 98 feet, based on pumping plant performance tests by Pacific Gas and Electric Company from 1972 through 1977. Shallow lifts are generally encountered within areas having adequate surface water supplies. The greatest lifts are encountered in developed areas where the surface water supply is inadequate and where ground water extraction has exceeded recharge. Examples of such areas are western Madera County and the uplands in Madera, Merced, and Stanislaus Counties.

Ground water pumping costs in 1982 ranged from about 20 to 30 cents per acre-foot per foot of lift in most of the San Joaquin HSA. Costs per acre-foot range from an average of about $12, with a 50-foot lift, to $40 in the eastern Madera County valley floor, with a lift of about 160 feet.

Reserve Supply

The 191,000 acre-feet of reserve water supply takes in Central Valley Project supplies for which contracts have not been signed, including that from New Melones Reservoir (see Chapter V for projected build-up in use of total CVP supplies). New Melones Reservoir has been the focus of controversy for several years.

DETAILED 1980 HYDROLOGIC BALANCES

The purpose of the following four tabulations is to provide a detailed analysis of the sources of water used (applied and net) in this HSA and to describe what happens to the water in the process of its use. The tabulations show the type of information displayed schematically for the entire State in Figure 27. Applied water totals in these tabulations do not necessarily agree with totals in Table 16 because such items as artificial recharge are counted as applied water to show in more detail the complex interrelationship between supply and use.

The net water supply and net water use tabulations are based on information developed for each subarea of the HSA. Therefore, in some cases, the values given for return flows sometimes include outflows from one subarea that become part of the water supply to downstream subareas within the HSA. A balance is obtained by including these quantities in the value given for local surface water supply. The sum of these return flows is shown as "Return Flow to Downstream Area in HSA."

DETAILED 1980 HYDROLOGIC BALANCES—SAN JOAQUIN HSA
(In 1,000s of acre-feet)

SOURCES OF APPLIED WATER	
Surface Water	
Local	3,066
CVP	1,715
Other Federal (non-CVP)	55
SWP	9
Waste Water Reclamation	21
Subtotal	4,866
Local Conveyance Loss to Groundwater	−507
Spillage to Downstream Areas in HSA	−203
Surface Reuse	
Urban	79
Agricultural	506
Wildlife	19
Subtotal	4,760
Ground Water	
Prime Supply	972
Artificial Recharge	76
Local Conveyance Loss	507
Deep Percolation From	
Urban Use	75
Agricultural Use	1,279
Wildlife	3
Withdrawal from Ground Water Storage	391
Subtotal	3,303
TOTAL	8,063

APPLIED WATER DISBURSEMENT	
Urban Use	
ETAW	139
Waste Water Reclamation	21
Return Flow to Downstream Areas in HSA	62
Other Losses	27
Reuse—Surface Water	79
Reuse—Ground Water	75
Subtotal	403
Agricultural Use	
ETAW	4,474
Return Flow to Delta	382
Return Flow to Downstream Areas in HSA	358
Riparian and Distribution System ET	298
Other Losses	177
Reuse—Surface Water	506
Reuse—Ground Water	1,279
Subtotal	7,474
Other Use	
Wildlife	
ETAW	64
Reuse—Surface Water	19
Reuse—Ground Water	3
Recreation	10
Energy Production—ETAW	15
Subtotal	111
Artificial Recharge of Ground Water	76
Total Need for Applied Water	8,064
Reduction in Use Due to Shortage	−1
TOTAL	8,063

San Joaquin HSA (Continued)

NET WATER SUPPLY

Local	3,055
CVP	1,838
Other Federal (non-CVP)	55
SWP	8
Waste Water Reclamation	21
Ground Water Prime Supply	972
TOTAL DEPENDABLE SUPPLY	5,949
Withdrawal from Ground Water Storage	391
TOTAL NET SUPPLY	6,340
Spillage to Downstream Areas in HSA	−203
Return Flow to Downstream Areas in HSA	−420
Return Flow to Delta	−382
TOTAL SUPPLY AVAILABLE FOR DEPLETIONS	5,335

NET WATER USE

Urban Use	
ETAW	139
Waste Water Reclamation	21
Return Flow and Spillage to Downstream Area in HSA	62
Other Losses	27
Subtotal	249
Agricultural Use	
ETAW	4,474
Return Flow and Spillage to Downstream Areas in HSA	561
Return Flow to Delta	382
Riparian and Distribution System ET	298
Other Losses	177
Subtotal	5,892
Other Use	
Wildlife	64
Recreation	10
Energy	15
Subtotal	89
Conveyance Losses (CVP)	111
TOTAL NET USE	6,340
Reduction in Use Due to Shortage	−1
Spillage and Return Flows to Downstream Areas in HSA	−623
Return Flow to Delta	−382
TOTAL DEPLETIONS	5,335

AVERAGE ANNUAL PRECIPITATION – 13,960,000 acre-feet

AVERAGE ANNUAL RUNOFF – 3,310,000 acre-feet

IRRIGATED LAND – 3,312,000 acres

POPULATION – 1,178,000

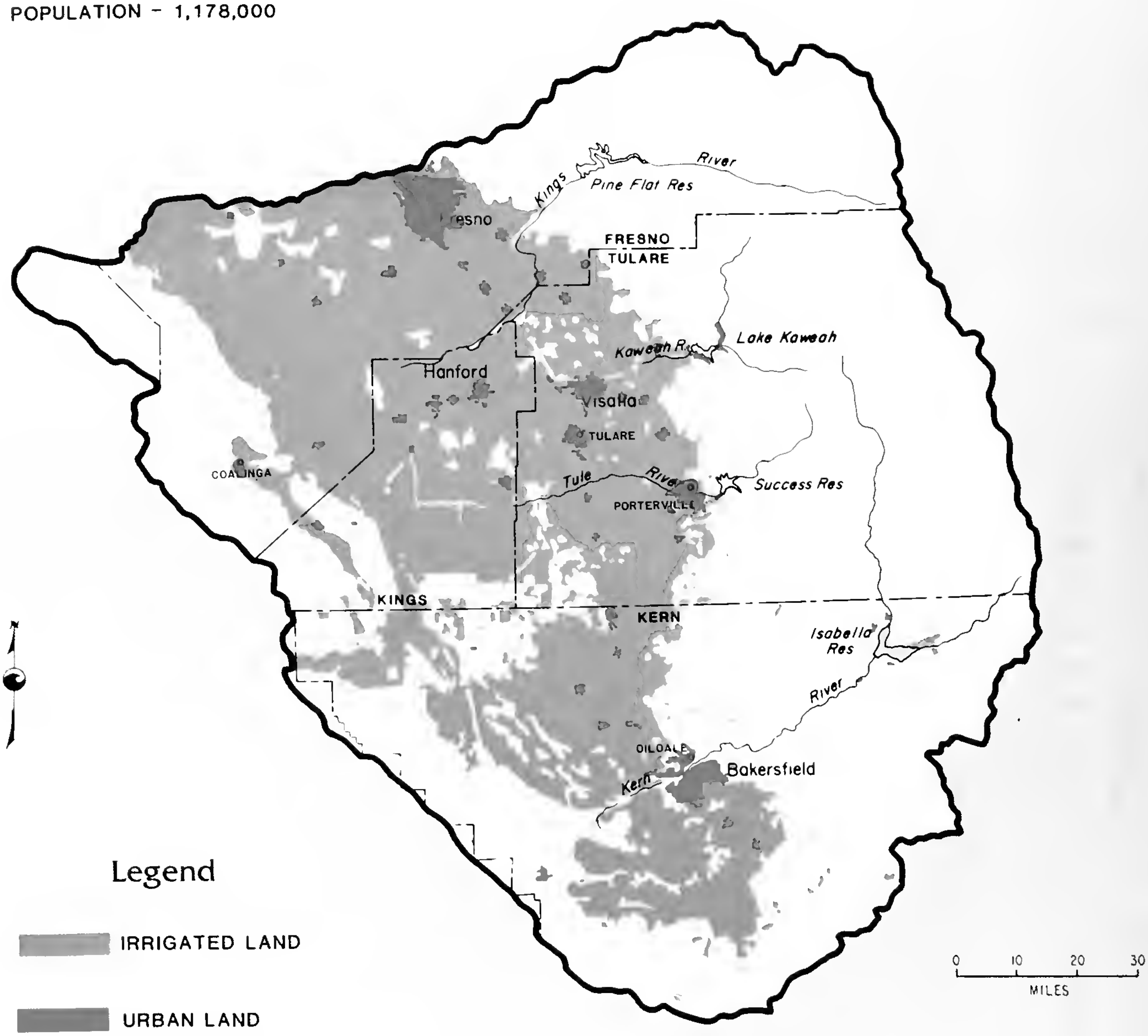


Figure 36.
TULARE LAKE HYDROLOGIC STUDY AREA

TULARE LAKE HYDROLOGIC STUDY AREA

Population

Growth in the Tulare Lake HSA between 1972 and 1980 was caused by expansion of existing industries, diversification of industries, and availability of affordable housing. The area's major employers are agriculture and government.

Irrigated Agriculture

Tulare Lake HSA encompasses one of the richest and most diverse agricultural areas in the world. In 1980, the gross value of agricultural production for this area was approximately $5 billion, more than one-third of the State's total for that year and more than three times its 1972 level of production.

Fresno, Kern, and Tulare Counties ranked first, second, and third, respectively, in gross value of agricultural production in California in 1980. Fresno County led all counties in the nation in 1980 with just over $2 billion. Moreover, 47 of the top 50 crops in the State, ranked according to value, were produced in Fresno County in 1980.

This large increase in gross value of farm production in the Tulare Lake HSA occurred because of sharply increased prices for many commodities, an increase in total irrigated acreage, and a larger proportion of total acreage devoted to production of higher value crops.

Growth of irrigated land in the Tulare Lake HSA between 1972 and 1980 amounted to more than 296,000 acres. About 100,000 acres of this land is situated in western and southern Kern County and is irrigated solely with water from the California Aqueduct (State Water Project). About 20,000 of 85,000 acres of newly irrigated land in central Kern County can be irrigated with either SWP water or ground water.

Cotton acreage soared during this period, increasing from about 715,000 acres in 1972 to a record high of nearly 1,300,000 acres in 1978, and then dropped to about 1,250,000 acres in 1980. Field corn, sugar beets, milo, pasture, and small grains were among the crops displaced by the growth in cotton acreage. Some of these crops also gave way to permanent crop plantings, which increased by over 100,000 acres. Almonds were the most prominent of these; almond plantings in Kern County doubled from 33,000 acres to 66,000 acres during this period. Wine grapes and soft fruits, primarily nectarines and plums, also figured prominently in the increase in permanent crops in eastern Fresno and Tulare Counties. Citrus acreage declined, most often being replaced by deciduous trees. Fig acreage continued to lose out to urban spread around the city of Fresno. More than 2,000 acres were displaced during the 1972–1980 period.

Reclamation of alkali lands in the Tulare Lake HSA continues. These lands adjacent to the basin trough are generally planted to field crops. Along the east side of the valley, rolling lands near the foothills are still being developed for orchard and grapes.

Drip irrigation has become prevalent in young orchards and many young vineyards. As energy costs increase and costs of pumping ground water rise, irrigation systems are being improved and new types of systems developed. The most significant improvement in irrigation has been the advent of laser-controlled land leveling. Laser technology, which is now in general use, allows for more precise land grading and thus more precise control of water. Most prominent among the newly developed systems is the linear-move sprinkler system, which provides extremely uniform and efficient water application.

Water Supply

Surface Water Supply

No new surface water storage projects have been constructed on local streams since Terminus Dam on the Kaweah River was completed in 1962. The aggregate active storage capacity on the San Joaquin, Kings, Kaweah, Tule, and Kern Rivers is only about 60 percent of the aggregate average annual runoff of these streams. Furthermore, dams along the foothill line on these streams were built by the U. S. Army Corps of Engineers with flood control as a primary purpose; therefore, much of the storage is reserved to control flood flows. The remaining conservation storage is used primarily for seasonal regulation of flows; long-term carryover storage is provided by the ground water basin.

Before deliveries from the Friant-Kern Canal began in 1950, local surface water development was the sole source of surface water deliveries to farmers. With the advent of the State Water Project (SWP) and the Central Valley Project (CVP), local streams accounted for only about 40 percent of the 7.3-million-acre-foot dependable water supply to the Tulare Lake HSA.

Ground Water Overdraft

Development of irrigated agriculture in the Tulare Lake HSA resulted in water demands that outstripped local water supplies as early as the 1930s. Historically, this HSA has led all other California HSAs in terms of the magnitude of overdraft. Annual average overdraft from 1958 to 1967 was 1.5 million acre-feet. In 1967, overdraft amounted to 1.8 million acre-feet, and in 1972, it had dropped to 1.3 million acre-feet. By 1980, estimated annual overdraft was reduced to almost 900,000 acre-feet by supplies from the CVP and SWP that totaled more than 4.2 million acre-feet.

The buildup of SWP deliveries in Kern County has greatly reduced the former severe overdraft that existed there. Since the critical drought year of 1977, large quantities of surplus SWP water have been made available to SWP Kern County water contractors, as well as to contractors in Kings County. In Westlands Water District west of Fresno, import of CVP surface water supplies has reduced (except for 1977) the former 1.0-million-acre-foot annual ground water pumping to about 100,000 acre-feet, and land subsidence has virtually ceased.

On the east side of the valley in Fresno, Kings, and Tulare Counties, ground water overdraft continues to increase, mostly where lands lying outside the boundaries of organized water agencies have been developed to irrigated agriculture without surface water supplies.

Ground Water Pumping Lifts and Costs

Based upon pumping plant performance tests made by the Pacific Gas and Electric Company (PGandE) from 1972 through 1977, ground water pumping lifts ranged from a minimum of 20 feet in the Centerville Bottoms area on the Kings River fan east of Fresno to more than 900 feet in western Kings County. At present, virtually all ground water extractions occur with lifts between 40 and 600 feet. The average pumping lift in the Tulare Lake HSA, weighted according to amount of pumping, is about 175 feet. The greatest pumping lifts are encountered on the west side of the valley in Fresno and Kings Counties, on the southern and eastern Kern County valley floor, and on the southeastern Tulare County valley floor.

Ground water pumping costs in 1982 ranged from about 20 to 30 cents per acre-foot per foot of lift in most of the Tulare Lake HSA. Southern California Edison Company (SCE) serves nearly all of Tulare County, about one-third of Kings County, and a small portion of Kern County. Historically, SCE's energy rates have been slightly higher than PGandE's.

Other than the extremely shallow and extremely deep lifts, ground water pumping costs range from about $15 per acre-foot (for a lift of 50 feet) to about $100 per acre-foot (for a lift of 500 feet). The average cost is about $40 for a lift of 175 feet.

TABLE 29

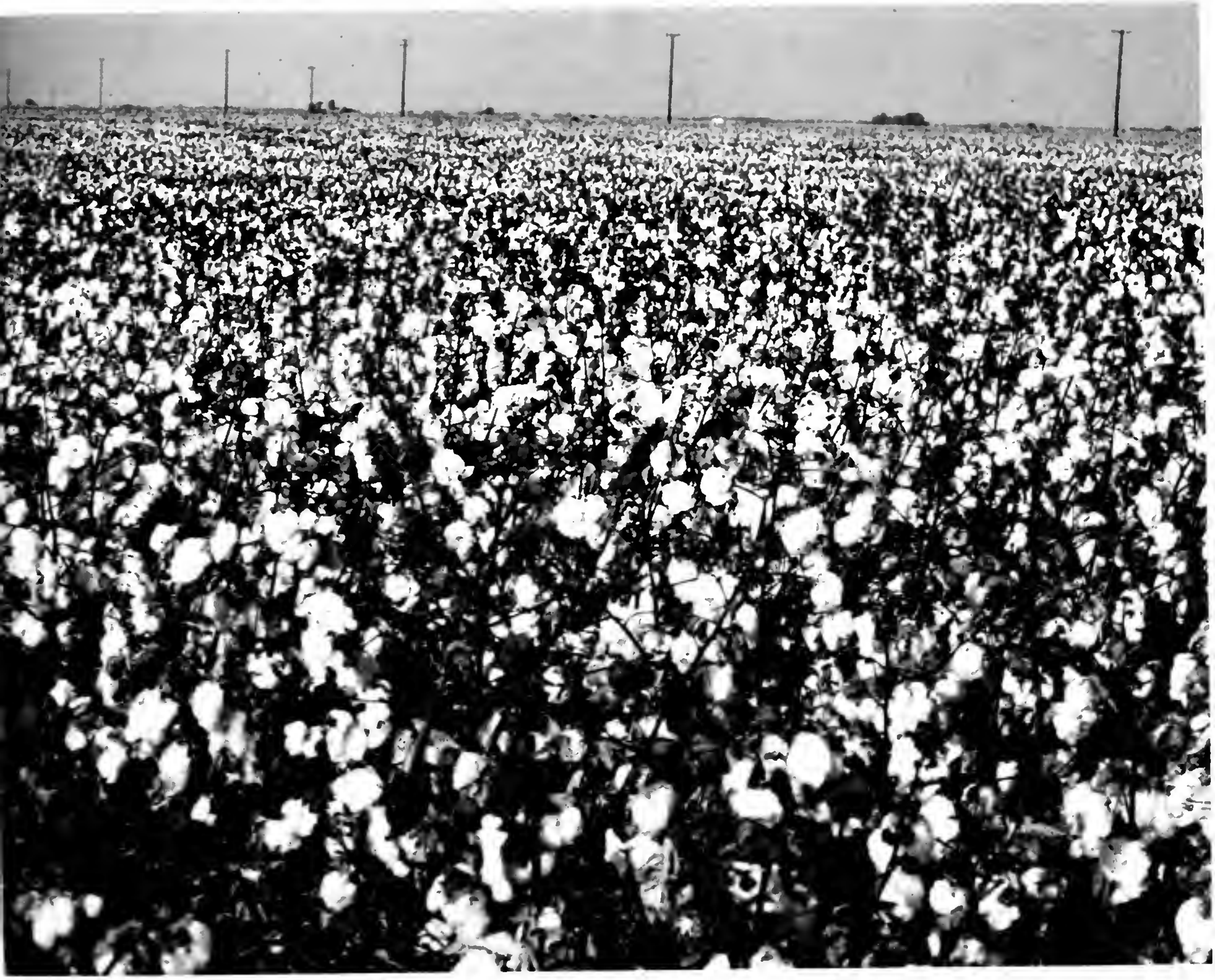
NET WATER USE AND WATER SUPPLY
TULARE LAKE HYDROLOGIC STUDY AREA—1980
(In 1,000s of acre-feet)

Net Water Use		*Dependable Water Supply*	
Urban	236	Local surface water	2,199
		Major local imports	—
Irrigated agriculture	7,781	Ground water	551
		Central Valley Project	2,736
Energy production	10	Other federal projects	243
		State Water Project	1,536 [1]
Wildlife and recreation	38	Waste water reclamation	67
Conveyance losses	123	Use of dependable water supply	7,332
		Reserve supply	56
TOTAL	8,188	TOTAL DEVELOPED WATER	7,388

WATER BALANCE

Net Water Use	*Use of Dependable Water Supply*	*Use Met by Ground Water Overdraft*	*Urban Shortage*
8,188	7,332	856	—

[1] Includes SWP surplus water deliveries



One of the largest increases in crap acreage has been catton
in the sauthern San Joaquin Valley.

DETAILED 1980 HYDROLOGIC BALANCES

The purpose of the following four tabulations is to provide a detailed analysis of the sources of water used (applied and net) in this HSA and to describe what happens to the water in the process of its use. The tabulations show the type of information displayed schematically for the entire State in Figure 27. Applied water totals in these tabulations do not necessarily agree with totals in Table 16 because such items as artificial recharge are counted as applied water to show in more detail the complex interrelationship between supply and use.

DETAILED 1980 HYDROLOGIC BALANCES—TULARE LAKE HSA
(In 1,000s of acre-feet)

SOURCES OF APPLIED WATER	
Surface Water	
Local	2,199
Local Reuse of Return Flows	82
CVP	2,643
Other Federal (non-CVP)	243
SWP	1,506
Waste Water Reclamation	67
Subtotal	6,740
Ground Water	
Prime Supply	551
Artificial Recharge	409
Deep Percolation from	
Urban Use	148
Agricultural Use	3,561
Wildlife	14
Incidental Reclamation	41
Withdrawal from Ground Water Storage	856
Subtotal	5,580
TOTAL	12,320

APPLIED WATER DISBURSEMENT	
Urban Use	
ETAW	151
Incidental Reclamation	41
Planned Reclamation	67
Evaporation	10
Flows to Salt Sinks	8
Reuse—Ground Water	148
Subtotal	425
Agricultural Use	
ETAW	7,326
Reuse—Surface Water	82
Reuse—Ground Water	3,561
Flows to Salt Sinks	276
Loss to Moisture-Deficient Soils	74
Evaporation from Local Conveyances	64
Evaporation of Return Flows	10
Evapotranspiration from Riparian Vegetation	31
Subtotal	11,424
Other Use	
Wildlife	
ETAW	31
Reuse—Ground Water	14
Recreation	7
Energy Production	
ETAW	3
Flows to Salt Sinks	7
Subtotal	62
Artificial Recharge	409
TOTAL	12,320

Tulare Lake HSA (Continued)

NET WATER SUPPLY

Local	2,199
CVP	2,736
Other Federal (non-CVP)	243
SWP	1,536
Waste Water Reclamation	67
Ground Water Prime Supply	551
TOTAL DEPENDABLE SUPPLY	7,332
Withdrawal from Ground Water Storage	856
TOTAL NET SUPPLY	8,188

NET WATER USE

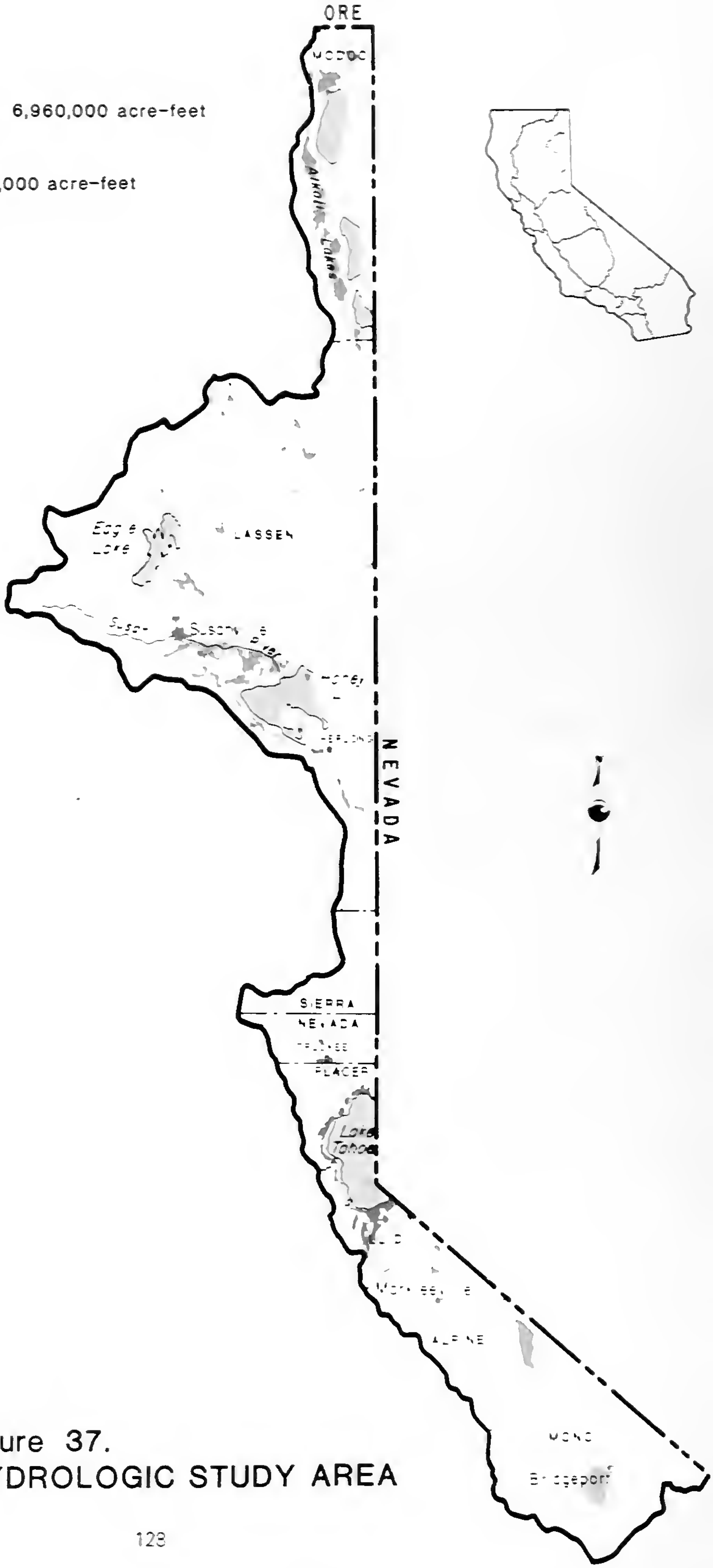
Urban Use	
ETAW	151
Planned Reclamation	67
Evaporation	10
Flows to Salt Sinks	8
Subtotal	236
Agricultural Use	
ETAW	7,326
Flows to Salt Sinks	276
Evaporation from Local Conveyances	64
Loss to Moisture-Deficient Soils	74
Evaporation of Return Flows	10
Evapotranspiration from Riparian Vegetation	31
Subtotal	7,781
Other Use	
Recreation	7
Wildlife	31
Energy Production:	
ETAW	3
Flows to Salt Sinks	7
Subtotal	48
Conveyance Losses	
CVP	93
SWP	30
Subtotal	123
TOTAL	8,188

AVERAGE ANNUAL PRECIPITATION - 6,960,000 acre-feet

AVERAGE ANNUAL RUNOFF - 1, 840,000 acre-feet

IRRIGATED LAND - 148,000 acres

POPULATION - 61,000



Legend

IRRIGATED LAND

URBAN LAND

Figure 37.
NORTH LAHONTAN HYDROLOGIC STUDY AREA

1980

NORTH LAHONTAN HYDROLOGIC STUDY AREA

Population

The population in the North Lahontan HSA, with the exception of the Lake Tahoe area, is characteristically sparse and widely scattered, and urban communities are relatively small. The largest, South Lake Tahoe, has a population of 21,000.

Between 1972 and 1980, this area experienced both the lowest numerical population increase and the highest rate of growth in California. The area has the highest ratio of single-to-multiple residences in the State, 84 percent single-family units and 16 percent multi-family units. Agriculture is the major economic activity in the North Lahontan HSA, and the raising of livestock predominates. Recreation and tourism are important economic activities in the Lake Tahoe area.

Irrigated Agriculture

Total irrigated acreage in the North Lahontan HSA has changed very little since 1972, but some notable changes have taken place in crop patterns, with irrigated grain and alfalfa replacing pasture land, principally in Surprise Valley. Major increases in the use of sprinkler irrigation for alfalfa have occurred there. Water formerly used to produce meadow hay is now more efficiently spread by wheel-line or center-pivot sprinkler systems to grow high-quality, high-dollar-return alfalfa.

Little change has taken place in total irrigated acreage south of Lake Tahoe. Irrigated pasture, 37,500 acres, and alfalfa, 3,600 acres, were the principal crops in this area in 1980. The limited amount of developed dependable water supplies has restricted the expansion of irrigated agriculture in this area. Topaz Lake near Coleville and Bridgeport Reservoir at Bridgeport are used largely to develop and regulate irrigation water supply.

TABLE 30
NET WATER USE AND WATER SUPPLY
NORTH LAHONTAN HYDROLOGIC STUDY AREA—1980
(In 1,000s of acre-feet)

Net Water Use		*Dependable Water Supply*	
Urban	23	Local surface water	312
		Major local imports	11
Irrigated agriculture	387	Ground water	88
		Central Valley Project	—
Energy production	—	Other federal projects	—
		State Water Project	—
Wildlife and recreation	11	Waste water reclamation	5
Conveyance losses	—	Use of dependable water supply	416
		Reserve supply	17
TOTAL	421	TOTAL DEVELOPED WATER	433

WATER BALANCE

Net Water Use	*Use of Dependable Water Supply*	*Use Met by Ground Water Overdraft*	*Urban Shortage*
421	416	5	—

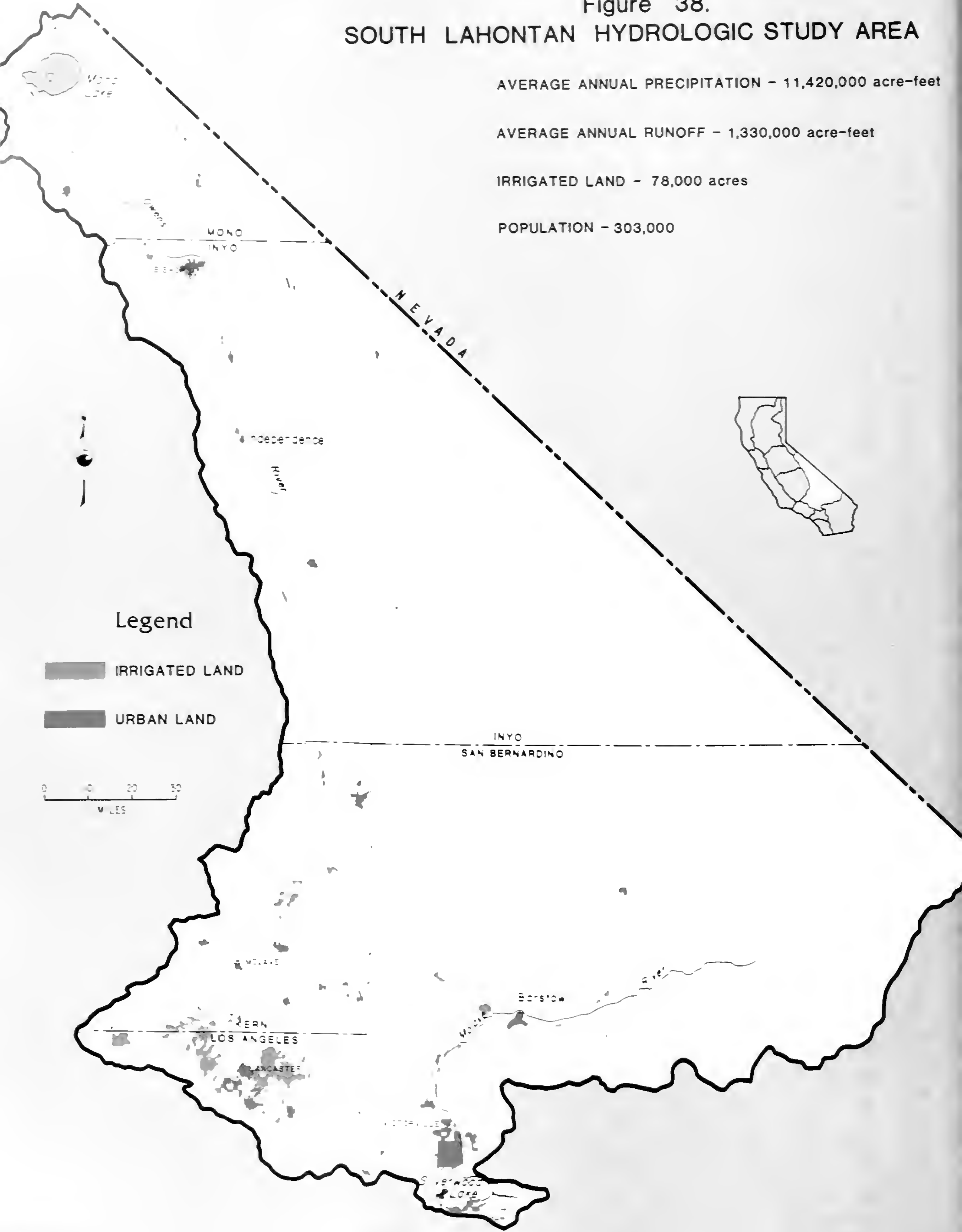
Figure 38.
SOUTH LAHONTAN HYDROLOGIC STUDY AREA

AVERAGE ANNUAL PRECIPITATION - 11,420,000 acre-feet

AVERAGE ANNUAL RUNOFF - 1,330,000 acre-feet

IRRIGATED LAND - 78,000 acres

POPULATION - 303,000



SOUTH LAHONTAN HYDROLOGIC STUDY AREA

Population

Government employment in the South Lahontan HSA has been growing in recent years because of increased activity at Edwards Air Force Base, the U.S. Naval Weapons Center, and the new federal prison at Boron. Mining activity has also increased in Kern County.

Irrigated Agriculture

Irrigation in the South Lahontan HSA has remained somewhat stable, with irrigated area and length of irrigation period increasing in wet years and decreasing in dry years.

Irrigation in the Mono-Owens area is regulated by the amount of water the city of Los Angeles releases locally.

Farmers in Benton Valley, northeast of the town of Bishop, have begun using center-pivot sprinklers for their alfalfa. Native pasture land irrigation continues with the wild flooding technique. In the areas of Indian Wells, Fremont, and Antelope Valley, irrigation of alfalfa continues with hand-move sprinkler systems, although center-pivot systems are also beginning to be used in Antelope Valley.

Agricultural production in Antelope Valley is likely to decline in the future because of falling ground water levels. Increasing prices for fossil fuel and electricity for pumping and greater competition with new urban developments for existing water supplies have caused some farmers to give more attention to improving irrigation efficiency in order to continue farming profitably.

TABLE 31

NET WATER USE AND WATER SUPPLY
SOUTH LAHONTAN HYDROLOGIC STUDY AREA—1980
(In 1,000s of acre-feet)

Net Water Use		*Dependable Water Supply*	
Urban	60	Local surface water	44
		Major local imports	—
Irrigated agriculture	338	Ground water	178
		Central Valley Project	—
Energy production	2	Other federal projects	—
		State Water Project	85
Wildlife and recreation	12	Waste water reclamation	9
Conveyance losses	7	Use of dependable water supply	316
		Reserve supply	33
TOTAL	419	TOTAL DEVELOPED WATER	349

WATER BALANCE

Net Water Use	*Use of Dependable Water Supply*	*Use Met by Ground Water Overdraft*	*Urban Shortage*
419	316	103	—

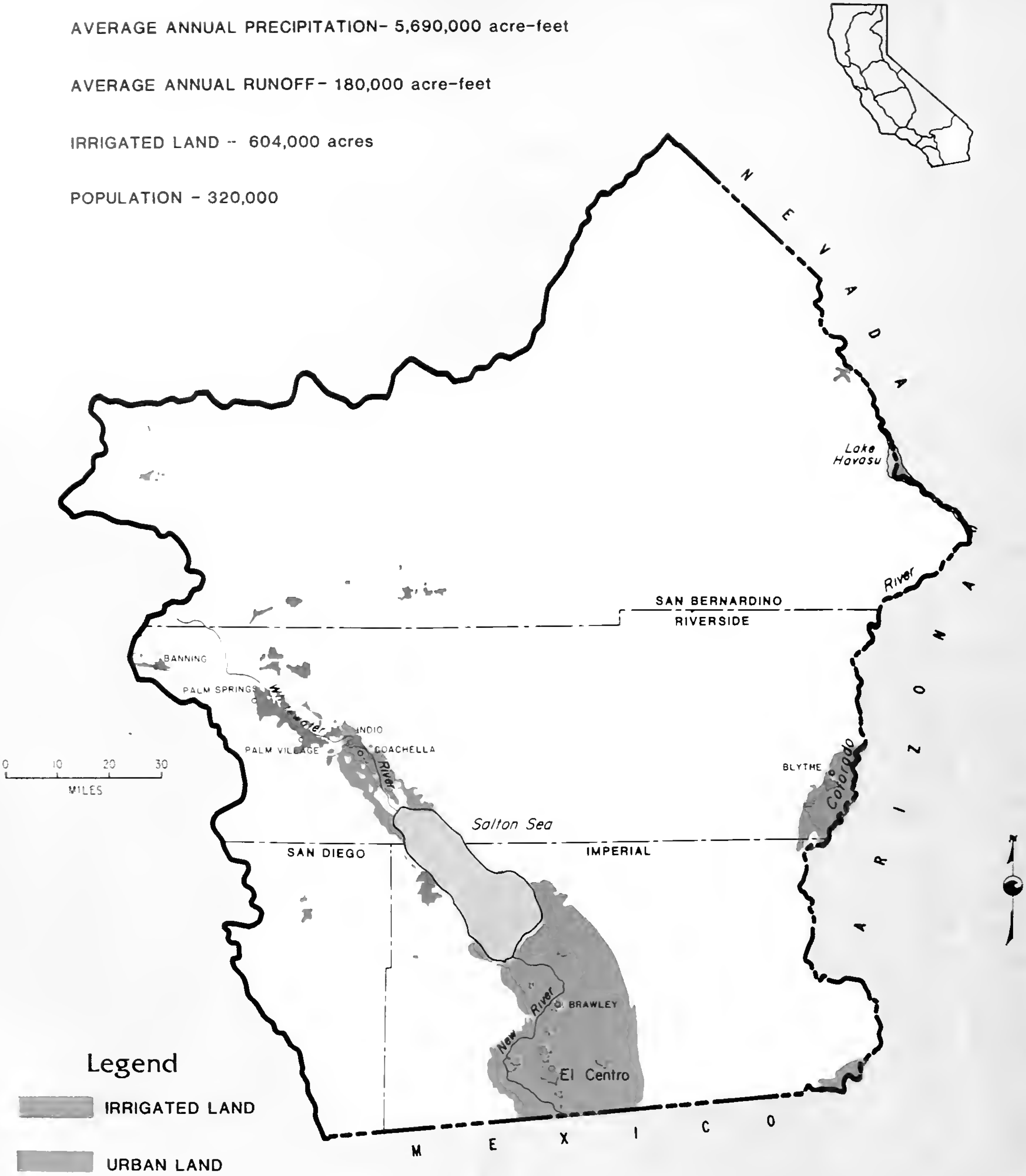


Figure 39.
COLORADO RIVER HYDROLOGIC STUDY AREA

1980

COLORADO RIVER HYDROLOGIC STUDY AREA

Population

Most of the population in the Colorado River HSA lives in the Coachella and Imperial Valleys. The major source of employment continues to be agriculture in the Imperial Valley. The city of Palm Springs in the upper Coachella Valley also provides substantial employment through the services and tourism sectors.

Imperial Valley has the second largest potential for geothermal power generation of any area in the nation. Development of this resource essentially began in 1980.

Irrigated Agriculture

Since 1972, irrigated acreage has increased slightly in Imperial, Palo Verde, and Chuckwalla Valleys. In Palo Verde Valley, irrigation has expanded on the mesa area with new plantings of alfalfa, cotton, jojoba, and wheat. These crops have been irrigated by sprinklers. The amount of double-cropping has varied from year to year. Irrigated land in Coachella Valley has declined because of urban encroachment.

A switch from furrow to drip irrigation systems in Coachella Valley for all varieties of grapes has improved the irrigation efficiency of this crop. Approximately 50 percent of the 10,000 acres of grapes in the area are irrigated with drip systems.

Water Conservation in Imperial Valley

Recent legal problems regarding disposal of agricultural drain water to the Salton Sea have resulted in increased efforts to more efficiently manage irrigation water. Steps being taken by the Imperial Valley Irrigation District to improve irrigation and conveyance efficiencies include lining the major lateral canals in the valley with concrete to reduce seepage losses, installing pumps next to the main unlined canals to pump seepage water back into the canal, and exacting assessments to penalize farms that produce excess irrigation runoff. A program designed to assist farmers in lining their own canals and ditches is being subsidized by the district.

A recent study by the Department of Water Resources, reported in *Investigation Under California Water Code Section 275 of Use of Water by Imperial Irrigation District*, identified opportunities and potential means for water savings. This study is discussed in Chapter V. The U.S. Bureau of Reclamation, with the cooperation of this Department and other agencies, is currently conducting an intensive study of the total water management system to further aid the District.

TABLE 32

NET WATER USE AND WATER SUPPLY
COLORADO RIVER HYDROLOGIC STUDY AREA—1980
(In 1,000s of acre-feet)

Net Water Use		*Dependable Water Supply*	
Urban	102	Local surface water	4
		Major local imports	—
Irrigated agriculture	3,434	Ground water	68
		Central Valley Project	—
Energy production	3	Other federal projects	3,970
		State Water Project	30
Wildlife and recreation	20	Waste water reclamation	3
Conveyance losses	543	Use of dependable water supply	4,075
		Reserve supply	4
TOTAL	4,102	TOTAL DEVELOPED WATER	4,079

WATER BALANCE

Net Water Use	*Use of Dependable Water Supply*	*Use Met by Ground Water Overdraft*	*Urban Shortage*
4,102	4,075	27	—

Lining ditches and canals is a major element in the continuing effort by the Imperial Irrigation District to reduce waste of water.

CHAPTER IV

FUTURE WATER USE—1980 TO 2010

This chapter basically is concerned with the development of estimates of future uses of water in California to 2010. Trends in population growth, market-place competition for agricultural produce, patterns in land use, water costs and prices, the impact of water conservation—these are the major factors having influence on future use of water in the State. These and other significant factors are discussed in this chapter. The projections include the following key findings.

- Total net water use is projected to increase about 10 percent over the next 30 years, compared to a 9-percent increase over the previous 8 years.
- The increase in urban net water use will exceed the increase in agricultural net water use.
- Population will continue to increase but at a slower rate.
- Statewide, irrigated cropland will continue to expand, although at a slower rate. Irrigated acreage is expected to increase significantly in the two major agricultural areas, the Central Valley and the Imperial Valley. The percentage increase in projected total State acreage between 1980 and 2010 is the same as the percentage increase that occurred between 1972 and 1980.
- Water conservation will significantly reduce the unit amount of water applied for both urban and agricultural purposes.
- The impact of water conservation on net water use will vary greatly, depending on the hydrologic characteristics of each area that influence the amount of reuse of excess applied water.

These and other projections reported in this chapter are based upon a series of key assumptions regarding water supply availability and costs. These assumptions, which are summarized in the next section of this chapter, were selected to represent the future circumstances and trends that seemed most probable at the time the studies were made. A basic premise was that, for any anticipated increase in net water use, an affordable water supply must be identified. This premise was particularly significant to the studies of future agricultural water use.[1]

The projection process consisted of several phases. Projections of agricultural water use required estimates of future irrigated crop acreages, irrigation efficiencies, and other water conservation-related considerations. Projections of urban water use required estimates of future population levels, including geographical distribution, and per capita applied water, including probable impacts of water conservation. In addition, estimates were made of future water use by wildlife management areas, by public parks (other than those included in the urban use estimate), for power plant cooling, and for enhanced oil recovery.

Computation of net water use required estimates of three elements: evapotranspiration of applied water, irrecoverable losses connected with water supply delivery, and outflow from the area of analysis. Estimated savings in water supply due to water conservation were based primarily on the reduction of return flow to the ocean, to saline ground water, and to other salt sinks.

Results of the Department's analyses of water use and water supply are summarized in this report by Hydrologic Study Areas (HSAs) for the entire State. The actual studies, however, were conducted by smaller analysis areas termed Planning Subareas (PSAs) and Detailed Analysis Units (DAUs). Planning Subareas are made up of Detailed Analysis Units, just as Hydrologic Study Areas are made up of Planning Subareas. The boundaries of all three areas are determined principally by hydrologic features, specifically the boundaries of stream drainage basins and ground water basins. However, except in the case of Hydrologic Study Areas, boundaries for large valley floor areas are commonly delineated to include the service areas of one or more water agencies, such as irrigation districts. In the major agricultural areas, a DAU typically covers 100,000 to 300,000 acres.

One of the purposes of periodically updating the California Water Plan is to identify water supply shortages and other water management problems.

[1] For agriculture, "affordable supply of water" means that the cost of water to farmers does not exceed their ability to pay it.

Northeastern California produces premium quality alfalfa hay.

Fundamental to the process is the examination of the current relationship between net water use and water supply (including the ways in which both may affect future water management needs), and the estimation of future net water use-water supply relationships. From these, future study needs are determined and the probable impacts of alternative water management decisions can be inferred. Future water use projections are presented by type of use in this chapter, while the relationship of water supply to those projections is addressed in Chapter V.

Assumptions of Water Supply Availability and Prices

To develop the projections of water use described in this chapter, certain assumptions were made regarding the amount—and, in the case of agriculture, the price—of the supplemental water supplies that would be available during the period of analysis, 1980–2010. These assumptions are summarized here, and some of them are discussed more fully in Chapter V. They were based on what were foreseen, at the time these studies were begun, as the most likely conditions to exist between 1980 and 2010.

Key Assumptions

- ***New Surface Water Facilities Will Be Developed As Scheduled.*** Preparation of this report began in 1979. The initial assumption was that the proposed SWP facilities (shown on Plate 1), as subsequently embodied in Senate Bill 200 (enacted by the Legislature in 1980), would be authorized and built as scheduled. In the June 1982 elections, however, the vote on Proposition 9 rejected SB 200. Accordingly, only those projects and programs not affected by Prop. 9 were included in projecting dependable water supplies for the SWP.[2]

  Federal project supplies assumed to be available during the analysis period were: New Melones Reservoir (CVP), San Felipe Division (CVP), and the Warm Springs Project (Corps of Engineers). Central Valley Project facilities that are not definitely scheduled but that could (if authorized and funded) become available before 2010 to meet supplemental water needs include Auburn Reservoir, the Mid-Valley Canal, and enlarged Shasta Lake. In addition, local agencies might complete several other water supply projects by 2010. These include the South Fork American River Project, the Cosumnes River Water and Power Project, and the North Fork Stanislaus River Project. Water supplies from these projects were not included in developing projections. If available, they would reduce identified shortages or ground water overdraft, depending on the particular area served.

- ***Availability of Colorado River Supplies Will Be Reduced.*** The Central Arizona Project will be completed on schedule, reducing California's firm right to Colorado River water to 4.4 million acre-feet annually by 1990. Of this amount, 55,000 acre-feet will satisfy water rights granted to the Indian tribes along the Colorado River,[3] and 3,000 acre-feet will satisfy present perfected rights of other local users.

- ***Diversion of Mono Lake Inflow Will Continue at Present Levels.*** The issue over preservation of Mono Lake, which involves possible reductions of existing water rights of the city of Los Angeles, will remain unresolved, and full diversions from the basin will continue.

- ***Instream Flow Requirements Will Remain Unchanged.*** No major change in instream requirements will occur for streams in which essentially all water is already appropriated (true of most of the Central Valley and Southern California). Furthermore, all existing instream requirements for wild and scenic river systems, flow maintenance agreements, water rights decisions, and basin water quality control plans not mentioned elsewhere in these assumptions will be unchanged. Relicensing of many hydropower plants will increase downstream release requirements, but these changes will not significantly affect water supplies for offstream uses, which, in most cases, are diverted farther downstream. The Trinity River fish flow release has been increased to 287,000 acre-feet per year and may later be increased to 340,000 acre-feet per year, as ordered in January 1981 by Secretary of the Interior Cecil Andrus.

- ***Use of Reclaimed Water Will Increase.*** Use of reclaimed water will be increased to the maximum extent feasible. Projected reclamation will be based on studies of local projects judged to have potential for implementation during the period of analysis. Limitations on use are based on public health standards that either exist or are assumed to exist at the time the project is added.

- ***Ground Water Use Will Remain Largely Unrestricted.*** Current trends in ground water use will not be significantly altered by changes in water rights laws. Ground water pumping will be essentially unrestricted, except for adjudicated basins and as reduced by availability of alternative supplies, economic constraints, and existing local management practices.

[2] An analysis was made to determine the impact of not developing the yield of SB 200 or equivalent facilities on schedule. The analysis indicated that most of the shortages in future deliveries to the SWP agricultural service areas in the San Joaquin Valley could be made up by increased ground water overdraft. However, no specific alternative supplies were identified to compensate for the potential shortages that would occur in the SWP urban service areas of Southern California.

[3] Present rights of the Indians are 55,000 acre-feet per year. An additional 82,000 acre-feet has been recommended by the special master, but this amount has not yet been adopted by the Supreme Court. For this report, it was assumed that the Indian tribes will not be granted the additional amount.

- ***Electrical Rates for Ground Water Pumping Will Increase.*** Electrical energy costs for ground water pumping were assumed to increase 2 percent per year in real terms; that is, in addition to the increase due to inflation.
- ***Ground Water Supplies Will Be Adequate.*** Additional ground water supplies will be obtained in the San Joaquin Valley through extraction of ground water in storage (overdrafting). Outside the San Joaquin Valley, new or greatly expanded ground water development is occurring in several areas of the State, especially in Northern California. Presently available information is insufficient to determine the potential for long-term sustained pumping from these basins. For this report, availability and cost of water in these areas were assumed to place no limits on the projections.
- ***Surface Water Price Increases Will Vary Widely.*** The price of water provided through currently authorized facilities by the U. S. Bureau of Reclamation will be increased as present contracts are renewed in the 1990s. State Water Project prices reflect the increase in energy costs with the expiration of initial contracts in 1983. The relative price of presently developed local surface water supplies will not change appreciably. The following examples of the approximate price of water per acre-foot (unescalated) from the State and federal systems do not include the cost of local distribution and treatment.

Further discussion of the effect of water prices on farm operations is presented in the sidebar, "Potential Impacts of Future Water Prices on Irrigated Agriculture."

	1980	1990	2000	2010
Federal (currently authorized facilities)				
Sacramento Valley	$3.50	$3.50	$9.00	$12.00
San Joaquin Valley (east side of the valley and Delta-Mendota Canal)	3.50	3.50	12.00	16.00
San Joaquin Valley (San Luis Service Area)	10.00	10.00	17.00	24.00
State				
South Bay Aqueduct	44.00	120.00	120.00	120.00
San Joaquin Valley (Kern County Water Agency)	29.00	80.00	80.00	80.00
Southern California (The Metropolitan Water District of Southern California)	123.00	275.00	275.00	245.00

Agricultural Water Use

California's agricultural producers not only compete actively in national and foreign markets but also with one another within the State. Moreover, they are in competition with importers who bring into California substantial quantities of food products from other regions of the United States and from foreign nations. An affordable supply of water for irrigated agriculture has allowed the State's producers to maintain a favorable competitive position. An identified source of affordable water was considered by the Department of Water Resources to be a prerequisite for projecting any additional development of irrigated land.

Projections of future net water use by irrigated agriculture are based on projections of crops. California was growing at least 200 commercial crops on 9.5 million acres of irrigated land in 1980.

Steps in the process of estimating future net water use by irrigated agriculture by decade to 2010 include:

- Determination of present crop acreages (see Chapter III).
- Determination of sources of affordable water supplies.
- Projection of crop acreages.
- Selection of unit evapotranspiration of applied water (ETAW) for each crop for each area.
- Estimation of increased irrigation efficiencies.
- Calculations of agricultural applied water and ETAW.
- Calculation of net water use, considering water reuse, total ETAW, distribution system irrecoverable losses, and outflow (see Chapter III for discussion of net water use).

The process employed to project crop acreages, depicted on Figure 40, involved analysis of potential markets, costs of water and other production factors, available land and water supplies, and outputs of several computer models. An economic model was employed to evaluate the impact of several factors on agriculture in the Central Valley, another model was used to analyze factors affecting feed and forage production, and other models were used to analyze markets and transportation costs. Information was obtained on historical specialization in specific crops; regional crop growing preferences; typical

crop rotation patterns; potential market outlook by crop; regional marketing structures; and acreage limits based on soil, water supply, and climate constraints. Information from all these sources and findings of various studies were integrated with information on current land use and land and water availability to provide crop projections for the entire State.

POTENTIAL IMPACTS OF FUTURE WATER PRICES ON IRRIGATED AGRICULTURE

Large variation exists in water prices around the State. Currently, districts that use CVP water charge farmers between $5 and $25 per acre-foot, while those using SWP water charge from about $10 to more than $40 per acre-foot. Variations in pumping lifts cause ground water costs to range from about $10 to more than $100 per acre-foot. Prices of water diverted from streams and local storage projects are generally lower.

Although significant increases are expected in some cases at some time in the future, changes will not be uniform, and the impact on agriculture will be variable. California's agriculture has a large share of the market for many of its products and the potential for a wide diversity of crop production due to the nature of its climate and soils. Farmers have demonstrated, at least partially, the ability to offset increases in the price of water by better irrigation management, by changing to higher value or lower water-use crops to the extent that market conditions allow, and by reducing other production costs.

The price of water today is a relatively small portion of total farm production costs. Water prices as a percentage of total production costs of 20 crops are given in Table 33. The effect of the price of water on net farm income is not as significant as the effect of some other factors. For a typical cotton grower, for instance, a 10-percent increase in the price of water will lower net income per acre by 7 percent, at most. A 10-percent decrease in the price of cotton or a 10-percent decrease in yield, on the other hand, can reduce a farmer's net income by as much as 40 percent. To state it another way, only a 1.5-percent increase in the yield or the price received for cotton would be needed to compensate for a 10-percent increase in the price of water. However, in some areas, the future percentage change in water prices will likely be much greater than the increase in prices received for crops or the increase in yield.

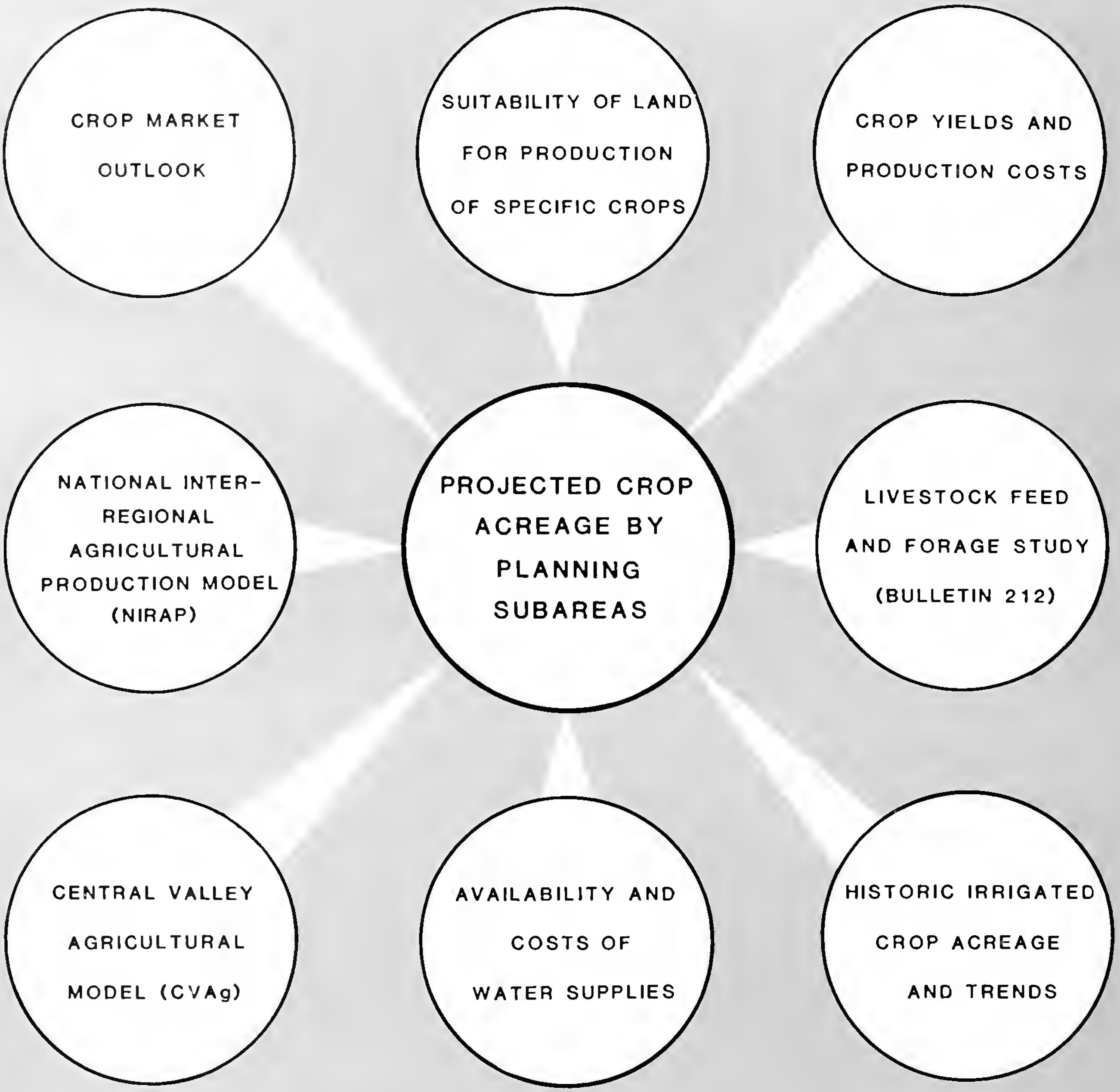
TABLE 33

1975 WATER COSTS AS A PERCENTAGE OF TOTAL CROP PRODUCTION COSTS FOR SELECTED REGIONS

	Kern and Kings Counties			*Tulare, Fresno, and Madera Counties*		
Crop	*Average*	*Low*	*High*	*Average*	*Low*	*High*
Cotton	19	9	26	10	4	29
Barley	19	6	26	11	4	24
Alfalfa	17	7	21	16	6	22
Wheat	21	9	26	10	5	22
Grapes	11	5	15	4	2	8
Sorghum	11	5	15	9	5	10
Sugar beets	22	9	27	16	5	27
Irrigated pasture	31	21	36	34	15	39
Oranges	20	11	31	6	3	11
Tomatoes	8	5	12	8	8	13
Rice	20	12	22	12	8	16
Carrots	6	2	7	—	—	—
Field corn	24	17	32	12	9	13
Onions	15	5	17	—	—	—
Almonds	—	—	—	4	2	7
Melons	—	—	—	7	9	15
Walnuts	—	—	—	7	3	12
Plums and prunes	—	—	—	3	1	5
Peaches	—	—	—	2	1	3
Lettuce	—	—	—	4	6	15

Source: University of California, Davis, *Agricultural Water Use and Costs in California*. Bulletin 1896, July 1980

Figure 40. STUDIES AND INFORMATION USED IN PROJECTING IRRIGATED CROPS



Studies and Considerations for Projecting Irrigated Crop Acreages

Several studies of the trends and influences of factors that affect irrigated agriculture in California were significant in guiding the projection of future irrigated crop acreage.

National Inter-Regional Agricultural Production Model. Information on future foreign and domestic markets for crops produced in California was obtained from analyses of the U. S. Department of Agriculture's National Inter-Regional Agricultural Production (NIRAP) model, which provided estimates of a growth rate for total crop production in the United States. The NIRAP model, developed by the U. S. Economic Research Service, is a computerized simulation of the food and agricultural system in the nation. The model consists of a series of equations, with variables for real prices, real income, and export demand, and several policy variables. Curves were plotted to display the model's results and then shifted in accordance with population increases or changes in relationships between variables in the economy. The NIRAP study indicated that:

- U. S. food exports will increase.
- California will maintain its present share of food exports.
- Per capita consumption of most foods and other farm products will remain at the present level until 2010.

Factors Affecting Competition from Other Producing Areas of the U. S. California accounts for more than 90 percent of the production of more than a dozen crops, mostly fruits and nuts. For many more crops, primarily vegetables, it is virtually the sole producer during certain times of the year. No change in competition is expected for such crops.

Future transportation costs and future availability of water for irrigation are two factors that will probably influence market competition between key productive regions in the nation for other crops. Transportation costs are likely to rise with increasing energy costs, and California's ability to compete with other areas in shipping specialty crops to eastern and midwestern regions of the United States may be affected. To help predict the impact, a study was undertaken for these important crops: cantaloupes, carrots, celery, table grapes, lettuce, nectarines, oranges, strawberries, and fresh tomatoes.

A cost-minimizing mathematical model was developed in which California, Arizona, Florida, and Texas were the principal competitors for these crops. New York City and Chicago represented eastern and midwestern markets. The purpose of the model was to determine how widely transportation costs could vary before a competing region could supply these foods less expensively than could California. Consumer demand was assumed to be at recent levels. The study indicated that, for many crops that compete with those in other states, California's producers and wholesalers will be able to accommodate large increases in real (inflation-adjusted) fuel costs before the marketing advantages of this State are lost.

To further assess California's ability to maintain its share of the market, the water supply situation in competing regions was considered. In two such areas, Arizona and the High Plains-Ogallala aquifer region, diminishing water supplies probably pose a more serious threat to agriculture than is the case in California. Arizona has taken strong measures to manage its precarious water demand-supply balance by enacting laws to control both agricultural and urban water use. In some parts of Arizona, no expansion of agriculture will be permitted, and, over time, some phasing out of existing irrigated acreage is expected.

The Ogallala is a ground water aquifer underlying a vast area in six of the High Plains states: Nebraska, Colorado, Kansas, New Mexico, Oklahoma, and Texas. The aquifer is the principal source of water for irrigation in this region. Since World War II, irrigated acreage has expanded tremendously, with the result that ground water overdraft is widespread—14 million acre-feet annually—in the Texas-Oklahoma High Plains area, and ground water levels have dropped significantly. Greater pumping lifts, coupled with high energy costs, have adversely affected crop production and cropping patterns. Without augmentation with surface water, irrigated land in parts of the

California leads the U.S. in the production of nectarines and other fresh fruit.

Cattle graze in an irrigated pasture in northeastern California.

region will likely revert to dry farming or rangeland over the next 30 years.

In Florida, there is concern that its major ground water aquifers cannot supply future needs, as was once thought. One-time recharge areas used to replenish the State's basins are now occupied by commercial and residential development, and large portions are underlain by salt-water deposits.

Thus, in several important instances, other areas of the United States that might otherwise compete with California in production of certain crops are facing severe water shortages. Therefore, over the long term, California is expected to retain or even improve its competitive marketing position for those crops.

Study of the Livestock Industry and Its Need for Feed and Forage. Although California is better known for its specialty fruits, nuts, and vegetables, its production of feed and forage crops presently accounts for about 40 percent of total applied irrigation water in the State. In recent years, beef production elsewhere has risen in relation to that in California. With the likelihood of increased water costs in some areas, questions have been raised regarding the ability of the State's livestock industry to maintain its competitive position in relation to other regions of the United States. To obtain a basis for projecting the State's future feed and forage production, the Department analyzed the livestock and poultry industries.

First, a study was conducted to assess changes in production methods, feed and forage consumption by animal type, and associated changes in feed and forage production from 1961 to 1978. Then, California's probable ability to continue in competition with other states in producing, transporting, and marketing livestock and poultry was analyzed. Finally, using the results of these studies, the opinions of an advisory committee composed of industry experts, and the results from an economic model, a most likely set of projections was developed of California's animal numbers and related acreages of feed and forage crops.[4] The study indicated:

- The rate of increase in beef consumption per person in California will gradually taper off to a level only 10 percent higher in 2010 than in 1976–1978.
- Poultry production in California will increase significantly, doubling the 1976–1978 level by 2010.
- Cattle marketing from California's feedlots is likely to continue its downward trend, although the trend will level off. Feedlot marketing in 2010 is expected to be the same as in 1976–1978. An increasing proportion of beef consumed in California will come from other states.
- Milk production per cow will continue to increase but not at the high levels of recent years. The number of milk cows in 2010 is expected to be 95 percent of the 1976–1978 level.

Based on these findings regarding livestock and poultry production trends, the study concluded that the potential demand for California-produced alfalfa hay, irrigated pasture, and feed grains in 2010 will be

Corn silage production is expected to continue as a significant agricultural activity.

[4] Details of these studies, including model descriptions, are given in the Department's report, *Outlook for Water Consumption by California's Feed and Forage Industry through 2010*, Bulletin 212, February 1982.

Almonds being harvested with a tree-shaker. Almost the sole producer of almonds in the U.S., California exports about half its crop. Almond acreage increased from 270,000 acres in 1972 to 370,000 in 1980 and is projected to continue expanding.

about the same as in 1976–1978. The study did not consider the impact of competition for land and water to produce other crops; however, this factor did enter into the final crop projection process. In the final analysis, because production of other crops will continue to increase, the proportion of total water used by feed and forage crops will continue to decline. The evapotranspiration of applied water (ETAW) by projected feed and forage crops will drop from about 40 percent in 1980 to about 33 percent of total agricultural ETAW in 2010.

Central Valley Agricultural Model. The Department also developed a linear programming model of Central Valley agriculture. The model considered 41 crops and incorporated data on crop yields, production costs, commodity demands, water costs, and land availability. It allocated acreages of crops among 54 Detailed Analysis Units (DAUs) in a pattern that would reflect maximum net farm income for the entire valley. Although the output did not necessarily represent what is likely to occur, crop by crop and DAU by DAU, it did indicate the overall impact on irrigated crop acreages of changes in water costs and expanded markets for agricultural products. The findings indicated:

- The crops that could be grown and where, given the assumed increases in energy and water costs and the availability of water and suitable land.
- The tendency toward increases or decreases in crop acreage with changing market conditions.
- The economic feasibility of additional irrigated acreage in the Central Valley.

With on-going modifications and additional experience in its use, the model can become a primary tool for projecting agricultural crops.

Other Information and Considerations. In addition to the models and related studies just discussed, a wide variety of other information, data, and expert judgment was called upon to provide the basis for the projection of irrigated crops. These included, for each area:

- Identified sources and prices of water supply.
- Historic pattern of land use.[5]
- Availability and suitability of land for potential development and changes in crop production.[5]
- Determination of the historic rate of development of irrigation.[5]
- Local factors that may influence cropping patterns (including apparent crop specialization or preferences).[5]
- Characteristics of undeveloped land, compared with those of adjacent irrigated land and other relevant site-specific information.[5]
- Market outlook information for specific crops, including the effect of general population growth and other recent or anticipated trends.

[5] The Department's land use maps, described in Chapter III, and its land classification maps, prepared to show the suitability of the land for specific irrigated crops, were the basis for this analysis.

Projections of Acreages of Irrigated Crops

The impact of the foregoing factors, including the model results, was translated into acres of specific irrigated crops in specific geographic areas. This work was carried out by Department staff members who have gained extensive knowledge of California's irrigated agriculture from their experience and responsibilities for land use and land classification mapping and agricultural economic studies. The advice and opinions of other knowledgeable people also were used. The results were projections of specific crop acreages in each study area (by DAUs in some cases; by PSAs in others). These are summarized by Hydrologic Study Area in Table 34 for 1980 and 2010.

TABLE 34

COMPARISON OF IRRIGATED CROP ACREAGE AND LAND AREA BY HYDROLOGIC STUDY AREA

1980 and 2010

(In 1,000s of acres)

Crop	NC	SF	CC	LA	SA	SD	SB	SJ	TL	NL	SL	CR	TOTAL
Grain[1]	30	5	5	—	20	5	420	250	420	10	5	190	1,430
	(30)	(5)	(9)	(2)	(29)	(13)	(399)	(275)	(500)	(10)	(17)	(157)	(1,466)
Rice	—	—	—	—	—	—	580	50	—	—	—	—	630
	—	—	—	—	—	—	(491)	(41)	(13)	—	—	—	(545)
Cotton	—	—	—	—	—	—	—	280	1,420	—	—	130	1,830
	—	—	—	—	—	—	—	(197)	(1,239)	—	—	(109)	(1,545)
Sugar Beets	—	—	5	—	—	—	75	70	5	—	—	40	195
	—	—	(10)	—	—	—	(59)	(56)	(39)	—	—	(36)	(210)
Corn	—	—	—	—	—	—	180	270	100	—	—	—	550
	—	—	—	—	—	—	(140)	(207)	(95)	—	—	—	(442)
Other field[2]	5	5	55	—	15	—	240	190	140	5	—	30	685
	(3)	(4)	(51)	(3)	(15)	(5)	(190)	(211)	(151)	(1)	(2)	(25)	(666)
Alfalfa	55	—	45	—	5	—	150	180	270	55	30	220	1,030
	(51)	(1)	(51)	(2)	(11)	(1)	(105)	(181)	(319)	(34)	(45)	(155)	(956)
Pasture	130	5	20	—	10	—	350	240	55	90	15	20	935
	(129)	(4)	(25)	(3)	(13)	(4)	(359)	(301)	(67)	(101)	(20)	(15)	(1,041)
Tomatoes	—	—	20	—	—	—	130	100	80	—	—	—	330
	—	—	(15)	—	—	—	(108)	(60)	(38)	—	—	—	(221)
Other truck[3]	25	10	310	50	20	20	55	120	160	—	—	150	920
	(15)	(15)	(271)	(51)	(21)	(15)	(32)	(86)	(115)	—	(2)	(119)	(749)
Almond-Pistachio	—	—	—	—	—	—	110	200	140	—	—	—	450
	—	—	—	—	—	—	(94)	(187)	(126)	—	—	—	(407)
Other deciduous[4]	10	5	25	—	5	—	210	190	190	—	—	—	635
	(9)	(10)	(32)	(2)	(2)	(1)	(173)	(145)	(153)	—	(2)	(1)	(530)
Citrus-Olive[5]	—	—	15	50	35	50	15	20	180	—	—	40	405
	—	—	(12)	(54)	(52)	(50)	(14)	(8)	(186)	—	—	(33)	(409)
Grapes	35	30	70	—	10	5	25	230	450	—	—	10	865
	(23)	(27)	(54)	(2)	(13)	(3)	(1)	(178)	(363)	—	—	(19)	(683)
TOTAL CROP ACRES	360	50	570	110	120	90	2,550	2,410	3,540	150	50	930	10,950
	(314)	(56)	(531)	(134)	(153)	(105)	(2,176)	(2,142)	(3,384)	(148)	(79)	(693)	(9,924)
DOUBLE CROP	—	—	35	25	10	10	150	150	130	—	—	150	730
	—	(2)	(70)	(15)	(8)	(6)	(92)	(80)	(70)	—	—	(89)	(434)
TOTAL LAND AREA	360	50	495	85	110	80	2,390	2,260	3,510	150	50	670	10,220
	(314)	(54)	(459)	(119)	(147)	(100)	(2,084)	(2,062)	(3,310)	(148)	(79)	(604)	(9,480)

Note: 1980 values are shown in parentheses.

[1] Primarily barley, wheat, oat grain, and grain hay.

[2] Dry beans, safflower, milo, sunflower, etc.

[3] Potatoes, melons, lettuce, etc.

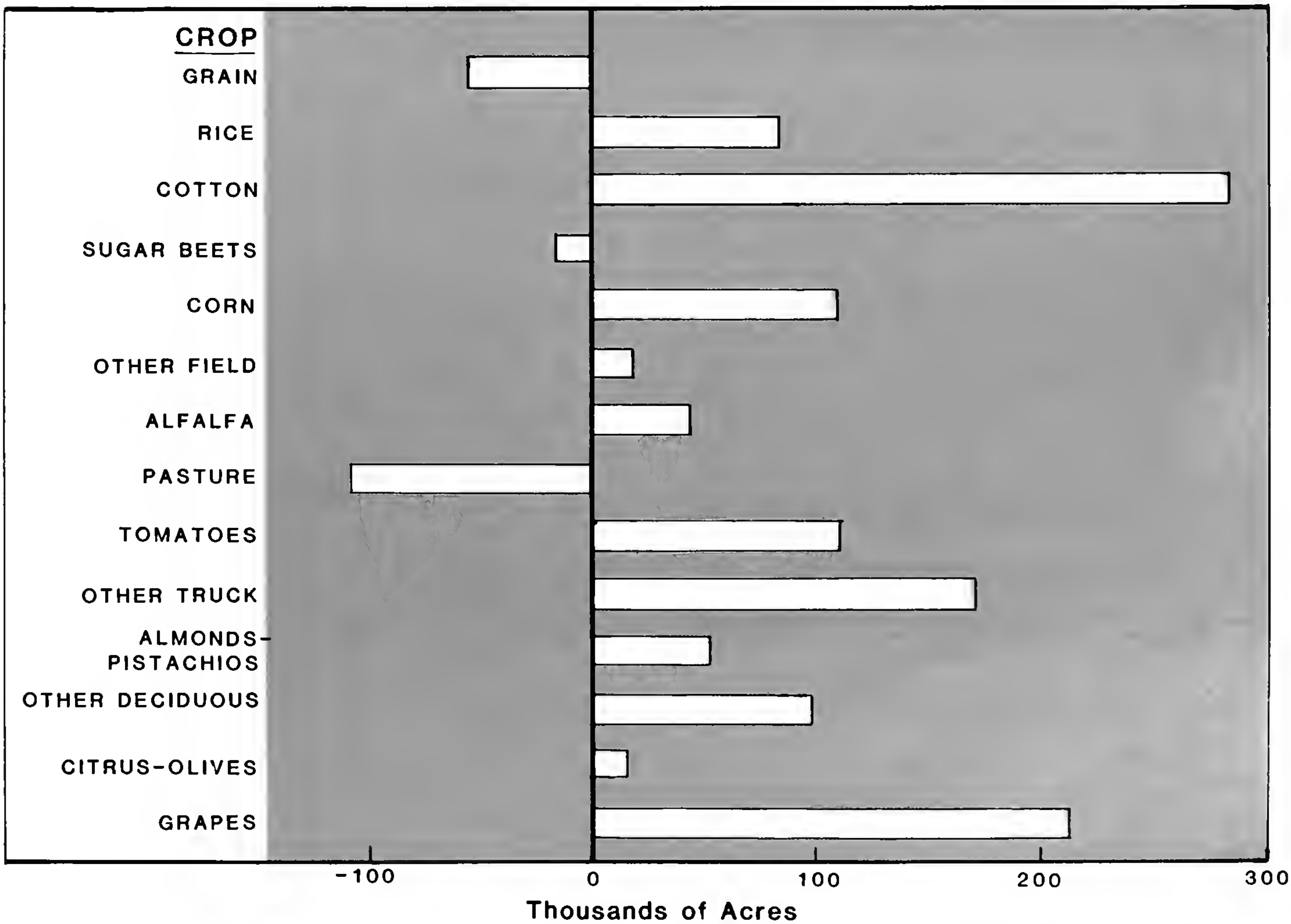
[4] Walnuts, peaches, prunes, plums, etc.

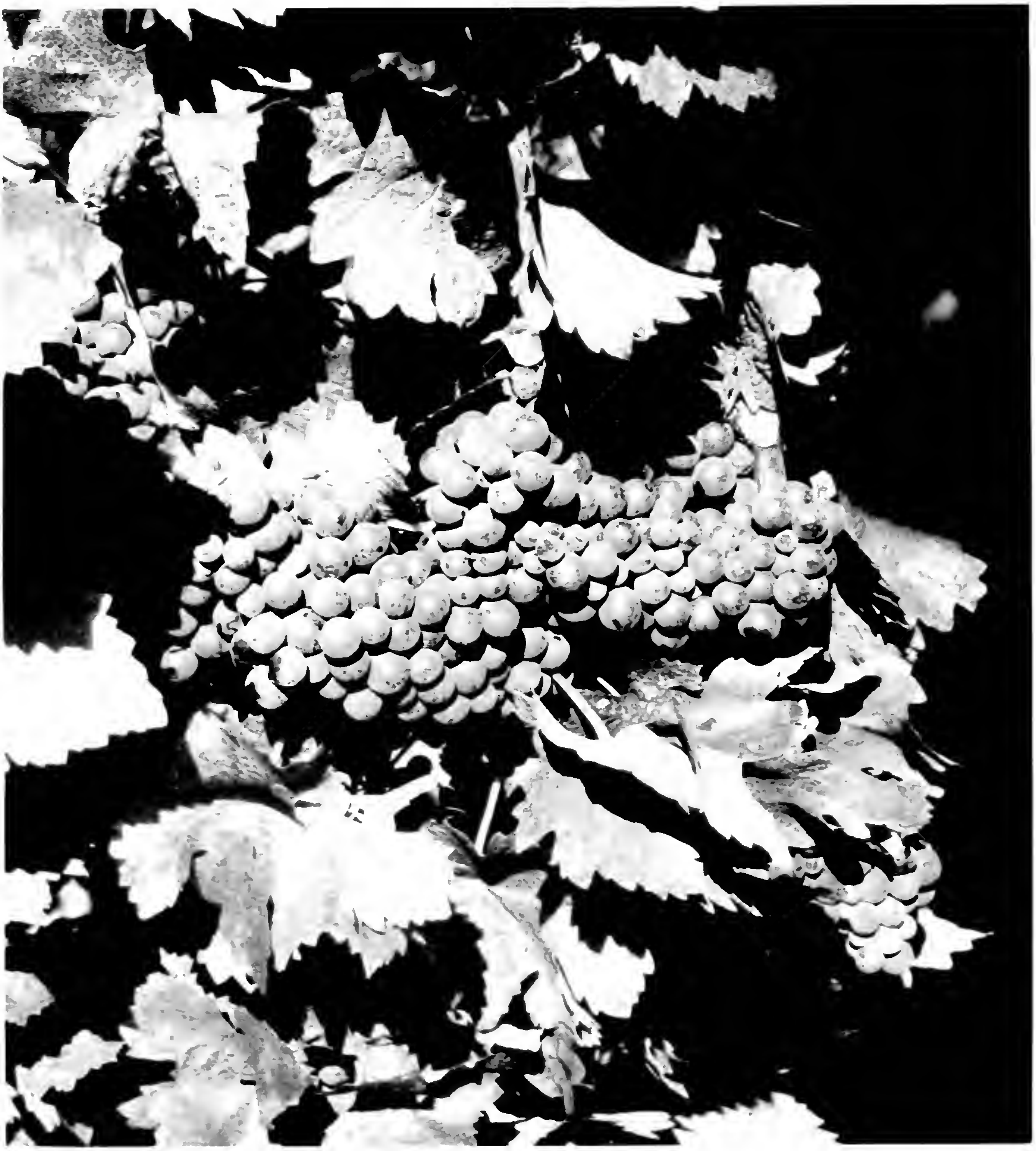
[5] Also includes avocados.

Some of the highlights of the projected changes in statewide irrigated acreage between 1980 and 2010 (Figure 41) are:

- ***Small Grains.*** Double cropping (grain plus another crop on the same land in one year) is expected to become more common; however, with the pressure of competition from other crops for land and water, total acreage of grain is expected to decrease slightly.
- ***Field Crops.*** Cotton and rice are projected to continue to dominate the San Joaquin Valley (cotton) and Sacramento Valley (rice). Corn is projected to increase about 25 percent. Although some changes are expected in the proportional mix, the total of all other field crops is expected to remain about level. These include dry beans, milo, safflower, and sunflower.
- ***Alfalfa and Pasture.*** The combined acreage of hay and forage crops is expected to remain about level, with irrigated pasture land giving way to higher income crops in some areas.
- ***Truck Crops.*** The total production of vegetables, berries, and nursery stock, which make up this category, is projected to increase about 30 percent, principally in keeping with growth of U. S. population.
- ***Tree Fruits and Nuts.*** Shifts in the ratios of specific fruits and nuts are expected; the total acreage should increase about 10 percent by 2010.
- ***Grapes.*** Wine grape production is projected to continue increasing. Total grape acreage will rise 30 percent by 2010.

Figure 41. CHANGE IN STATE TOTAL IRRIGATED ACREAGE, BY CROPS 1980 TO 2010





Wine grape acreage continues to grow markedly, with another 15,000 acres planted in 1980.

California produces more than half the nation's nine major processed vegetables, including green lima beans, here being harvested for freezing. Production of these and other processed vegetables in the State is expected to increase.

Total irrigated land in California (Table 35) is projected to increase from the 1980 level of 9,490,000 acres to 10,220,000 acres by 2010, an 8-percent increase over the 30-year period. This percentage increase is the same as that which occurred in the eight years between 1972 and 1980. The intensity of land use is expected to increase, reflected in increased double cropping. With double cropping, total irrigated crops are expected to increase by 10 percent to 10,950,000 acres.

The greatest expansion in irrigation is projected to occur in the Sacramento HSA, with irrigated land growing by 300,000 acres and double cropping increasing by 70,000 acres. The San Joaquin and Tulare Lake HSAs are each projected to increase total irrigated crops by about 250,000 acres. These projections for the Central Valley were given limited testing to determine how they would be affected by major

TABLE 35

IRRIGATED CROP ACREAGE AND LAND AREA BY HYDROLOGIC STUDY AREA BY DECADES TO 2010
(In 1,000s of acres)

Year	*NC*	*SF*	*CC*	*LA*	*SA*	*SD*	*SB*	*SJ*	*TL*	*NL*	*SL*	*CR*	*TOTAL*
IRRIGATED CROP ACREAGE [1]													
1980	314	66	531	134	153	105	2,176	2,142	3,384	148	78	693	9,924
1990	340	60	560	130	140	100	2,420	2,210	3,470	160	70	750	10,410
2000	350	60	570	120	130	100	2,480	2,300	3,540	160	60	810	10,680
2010	360	60	570	110	120	90	2,550	2,410	3,640	160	50	830	10,950
1980 to 2010 change	+46	−6	+39	−24	−33	−15	+374	+268	+256	+12	−28	+137	+1,026
IRRIGATED LAND AREA													
1980	314	64	459	118	147	100	2,084	2,062	3,312	148	78	604	9,490
1990	340	60	480	110	130	100	2,290	2,110	3,370	160	70	630	9,850
2000	350	60	480	100	120	90	2,340	2,180	3,430	160	60	660	10,030
2010	360	60	485	85	110	80	2,390	2,260	3,510	160	50	670	10,220
1980 to 2010 change	+46	−4	+26	−33	−37	−20	+306	+198	+198	+12	−28	+66	+730

[1] Includes double crop.

changes in the assumptions regarding water availability and energy costs. These results are reported in the sidebar "Effects of Alternative Assumptions for Water Supply and Energy Costs."

A projected irrigation water saving through conservation in the Colorado River HSA made it possible to project an increase in irrigated crop acreage of about 140,000 acres, half from newly developed land and half from increased double cropping. Some lesser increases are projected for the North Coast, Central Coast, and North Lahontan HSAs. Urban encroachment on presently irrigated lands will reduce such land in the San Francisco Bay, Los Angeles, Santa Ana, and San Diego HSAs by a total of nearly 100,000 acres. Irrigated land in the South Lahontan HSA is projected to decrease by about 30,000 acres because declining ground water levels and increased costs of energy will make ground water too costly for some farming operations. Further importation is no solution in the South Lahontan HSA because SWP prices exceed the ability of agriculture in that area to pay for water.

The complexity of factors that influence California's agriculture is such that projecting long-range agricultural activity with accuracy is unlikely. However, barring such events as major economic problems at the national or international level, devastating pest invasions, or similar situations that cannot be foreseen, irrigation can be expected to continue increasing as long as suitable land and affordable water are available.

EFFECTS OF ALTERNATIVE ASSUMPTIONS FOR WATER SUPPLY AND ENERGY COSTS

Projections of irrigated crops to 2010 were based on (1) certain assumptions regarding the timing of availability of additional surface water supplies and (2) the premise that real energy prices would increase steadily at the rate of 2 percent per year. It now appears that new SWP water supplies will not be made available as soon as had been assumed. Moreover, some experts believe that real energy prices will not increase beyond 1982 levels for at least the next 10 years.

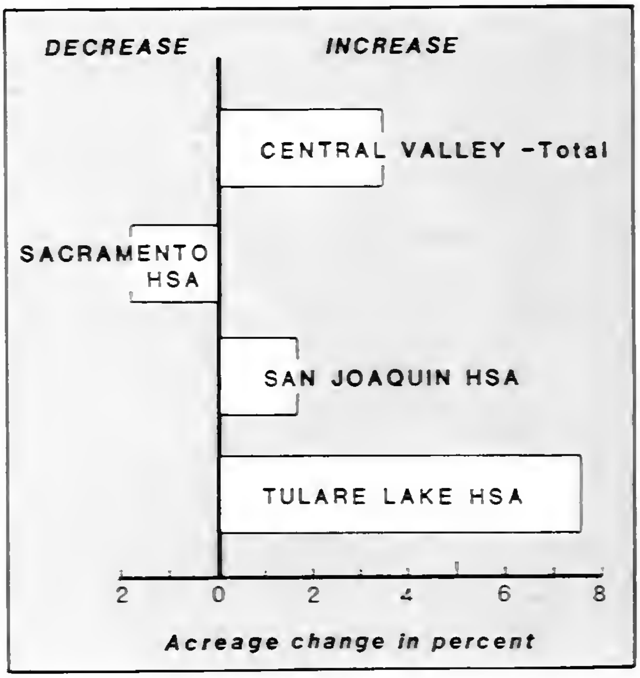
The possible effects of these alternative assumptions on irrigated agriculture were estimated by using the Central Valley agricultural model referred to in this chapter.

If energy prices increase only at the rate of inflation, the farmer's costs for fertilizer, equipment, operation, and water would be less, compared to costs with a 2-percent increase per year in real energy prices. The lower water costs would be particularly significant in those areas requiring energy to pump water from the Delta and in those areas that rely extensively on ground water. According to the model analysis, the net effect of constant energy prices, *compared to the projected 2-percent increase in real energy costs,* would be:

- An average annual increase in irrigated crop acreage of 50,000 acres in the Central Valley, compared to 30,000 acres with a 2-percent increase.
- A different crop acreage distribution within the valley.
- Some changes in cropping patterns.

The effect on the projected acreage by 2010 among areas in the Central Valley is shown graphically in the accompanying figure.

PERCENTAGE CHANGE IN PROJECTED 2010 ACREAGE FROM CONSTANT REAL ENERGY PRICES



The more optimistic energy price forecasts have the greatest impact in the Tulare Lake HSA because of its reliance on ground water supplies and use of SWP surface supplies, both of which are energy-intensive. Increases there in irrigated acreage would be offset, in part, by reductions in the Sacramento HSA, reflecting the greater competitive advantage in the Tulare Lake HSA.

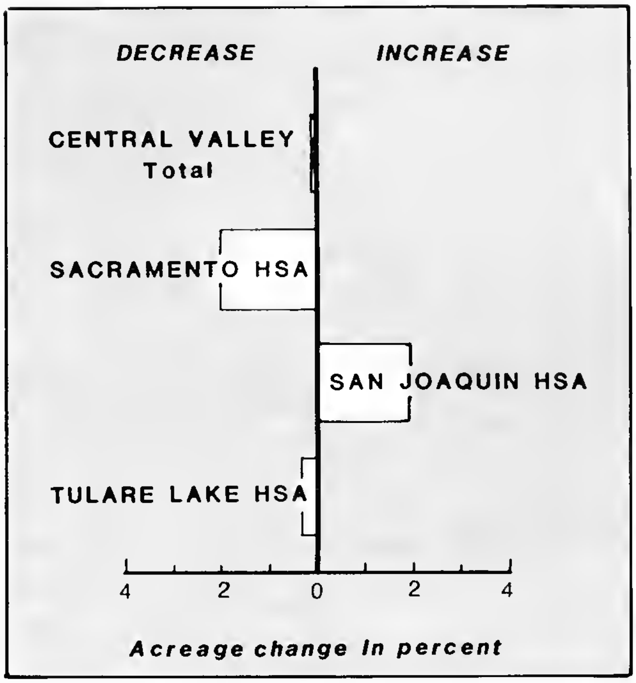
A delay in providing additional SWP facilities to meet projected requirements would not cause the change in total projected acreage that the energy price scenario would cause. With no additional SWP facilities, upstream depletions resulting from further development in the Sacramento Valley would reduce present yield from 2.3 million to 1.7 million acre-feet. The model analysis indicates that, under this supply reduction scenario, the following changes would take place.

- Ground water pumping would increase in the Tulare Lake HSA to make up for much of the SWP supply deficiency in that area.
- With the increased overdraft and resultant greater pumping lifts, ground water would become more expensive than would SWP supplies, but farming would still be profitable.
- Crop acreage would be distributed differently among Central Valley HSAs.
- Acreage would be slightly lower in the Tulare Lake HSA, higher in the San Joaquin HSA, and lower in the Sacramento HSA, compared to projections based on no delay in providing additional SWP facilities. The net change in the Central Valley would be almost negligible, however, as illustrated in the accompanying figure.

The primary shift predicted by the model would be a small movement from relatively water-intensive cotton to less water-intensive grains. This is the reverse of the trend indicated under the constant energy price scenario. Moreover, shifts in competitive advantage cause more of a chain reaction under the reduced water supply scenario than with the constant energy price scenario. As farmers in the Tulare Lake HSA move from cotton to grain acreage, the San Joaquin HSA would shift from grain production to increased acreage of other crops at the expense of smaller increases in Sacramento HSA production.

In summary, from the indicated changes in crop distribution and changing rate of annual increase in crop acreages, it is obvious that the assumption of reduced SWP deliveries has a lesser impact on crop production than do changes in energy price.

PERCENTAGE CHANGE IN PROJECTED 2010 ACREAGE RESULTING FROM REDUCED SWP SUPPLY



MAJOR CROP PATTERN CHANGES BY 2010 AS A RESULT OF ALTERNATIVE ASSUMPTIONS

AREA	CONSTANT ENERGY PRICES		NO ADDITIONAL SWP FACILITIES	
	Gain	Loss	Gain	Loss
CENTRAL VALLEY-TOTAL	COTTON GRAPES	GRAIN SUGAR BEETS TOMATOES	GRAIN	COTTON
SACRAMENTO HSA	GRAIN	SUGAR BEETS CORN GRAPES		PASTURE GRAPES
SAN JOAQUIN HSA	PASTURE GRAPES	FIELD CROPS TOMATOES	PASTURE GRAPES	
TULARE LAKE HSA	COTTON GRAPES	GRAIN	GRAIN	COTTON

Rice harvester. Average irrigation efficiency for rice is projected to rise from the present 45 percent to about 55 percent by 2010.

Future Changes in Irrigation Efficiency

California's irrigation, historically, has continuously become more efficient.[6] Taking the State as a whole, the weighted average irrigation efficiency has been steadily rising, as new systems with higher efficiencies are brought into use and the management of existing systems is improved. System changes have continued to take place because of the:

- Need to replace worn-out irrigation systems, often resulting in installation of better-designed systems.
- Desire to convert to systems requiring less labor, some of which are easier to operate efficiently.
- Interest in new types of equipment for specialized applications that prove to be more advantageous and are usually more efficient than their predecessors.

The new types of equipment include drip systems, linear-move and center-pivot systems, electronically controlled systems, and laser-leveled surface flood systems. An apparent trend toward greater skill in overall farm management has meant more care given to irrigation scheduling. These improvements have been observed even where water price is only a very small part of total operation cost.

Despite this trend toward greater efficiency, however, some notable exceptions do occur. Low efficiencies are still found in some mountain valleys where low-value pasture land is irrigated by stream diversions that usually provide less than a full season's water supply. The low economic return from pasture and the uncertainty of the water supply have not been conducive to investment in improved irrigation systems. An example is part of Honey Lake Valley in Lassen County. Low efficiencies also occur where systems of unlined canals built many years ago deliver low-priced water on a fixed schedule, as in the rice-growing areas of Sacramento Valley. At the other extreme, high efficiencies have long been common where irrigation water is relatively scarce and costly. These conditions prevail in San Diego County and parts of San Joaquin Valley, where maximum practical efficiency has been reached in many cases.

Overall, irrigation efficiency is expected to continue to increase and, with increasing costs of energy, labor, water, and other production factors, is likely to

[6] Irrigation efficiency, the percentage of the irrigation water used by the plant and evaporated from the soil, is the efficiency with which a farmer applies water; it should not be confused with the efficiency of operation of an irrigation district or the efficiency of a total hydrologic system, the values for each of which are derived from a different basis.

accelerate in some areas. However, in other cases, even where water price is low, measurements of water application rates indicate that under-irrigation is occurring, and improved irrigation management may actually increase water application, with concomitant increases in production.

For this study, future levels of irrigation efficiency were estimated for each crop or group of crops by each DAU. These estimates were based on evaluation of:

- Historic and current irrigation efficiencies.
- Range of soil characteristics and normal climate patterns.
- Current irrigation systems and irrigation practices.
- Current and expected future water prices (including energy cost impacts).
- Characteristics and operation of surface water distribution systems.

Although efficiencies of 80 percent or more can be achieved under ideal conditions, such rates rarely occur because of variations in soil characteristics, water quality, water prices, water delivery systems, and farming practices. Thus, in most cases, the weighted average irrigation efficiency estimated for 2010 for any crop over a relatively large area does not exceed 70 to 75 percent.

The variation in values is demonstrated by information shown in Table 36, which compares the weighted average irrigation efficiency for a number of crops in the:

- Maricopa-Wheeler Ridge DAU (composed of most of the Maricopa-Wheeler Ridge Water Storage District, a portion of the Arvin-Edison Water Storage District, and some unorganized areas).
- Kern Valley Floor PSA (composed of the Maricopa-Wheeler Ridge DAU and seven other DAUs).
- Tulare Lake HSA (composed of the Kern Valley Floor PSA and two other PSAs).

The table demonstrates the influence of the many variables on the weighted average irrigation efficiency as increasingly larger areas are considered.

Agricultural Applied Water and Net Water Use—1980 and Projected

Agricultural applied water and ETAW were computed by DAUs, aggregated by PSAs for the hydrologic analysis, and summarized by HSAs. Applied water and ETAW were computed from the projected crop acreages, unit applied water, and unit ETAW. A hydrologic analysis considering reuse, ETAW, irrecoverable distribution system losses, and outflow from each PSA provided the estimate of net water use.

Total agricultural applied water and related net water use by Hydrologic Study Area for 1980, 1990, 2000, and 2010, and changes in agricultural net use between 1980 and 2010 are presented in Table 37. The total change in agricultural net water use from 1980 to 2010 is depicted in Figure 42. The largest increase in net water use is projected to occur in the Tulare Lake HSA, followed closely by the San Joaquin and Sacramento HSAs. In total, net water use by agriculture in the Central Valley is projected to increase by more than 1.6 million acre-feet between 1980 and 2010. Conversely, the San Francisco Bay, Los Angeles, Santa Ana, and San Diego HSAs are expected to reduce their agricultural net water use by a total of nearly 250,000 acre-feet per year. Net water use in the South Lahontan HSA is expected to decline about 100,000 acre-feet from 1980 to 2010.

TABLE 36
EXAMPLES OF WEIGHTED AVERAGE IRRIGATION EFFICIENCIES BY CROP
1980 and 2010
(In percent)

	Maricopa-Wheeler Ridge DAU		*Kern Valley Floor PSA*		*Tulare Lake HSA*	
Crop	*1980*	*2010*	*1980*	*2010*	*1980*	*2010*
Grain	71	75	65	73	70	74
Cotton	69	75	68	74	67	72
Corn	69	70	65	69	58	65
Other field crops	70	75	63	74	64	69
Alfalfa	70	75	59	64	62	67
Pasture	69	75	49	52	51	57
Tomatoes	70	75	70	72	70	73
Other truck crops	70	75	70	74	69	73
Almonds-pistachios	69	75	65	74	66	73
Other deciduous	71	75	67	73	66	71
Citrus-olive	69	75	70	78	67	70
Grapes	80	80	70	75	56	59

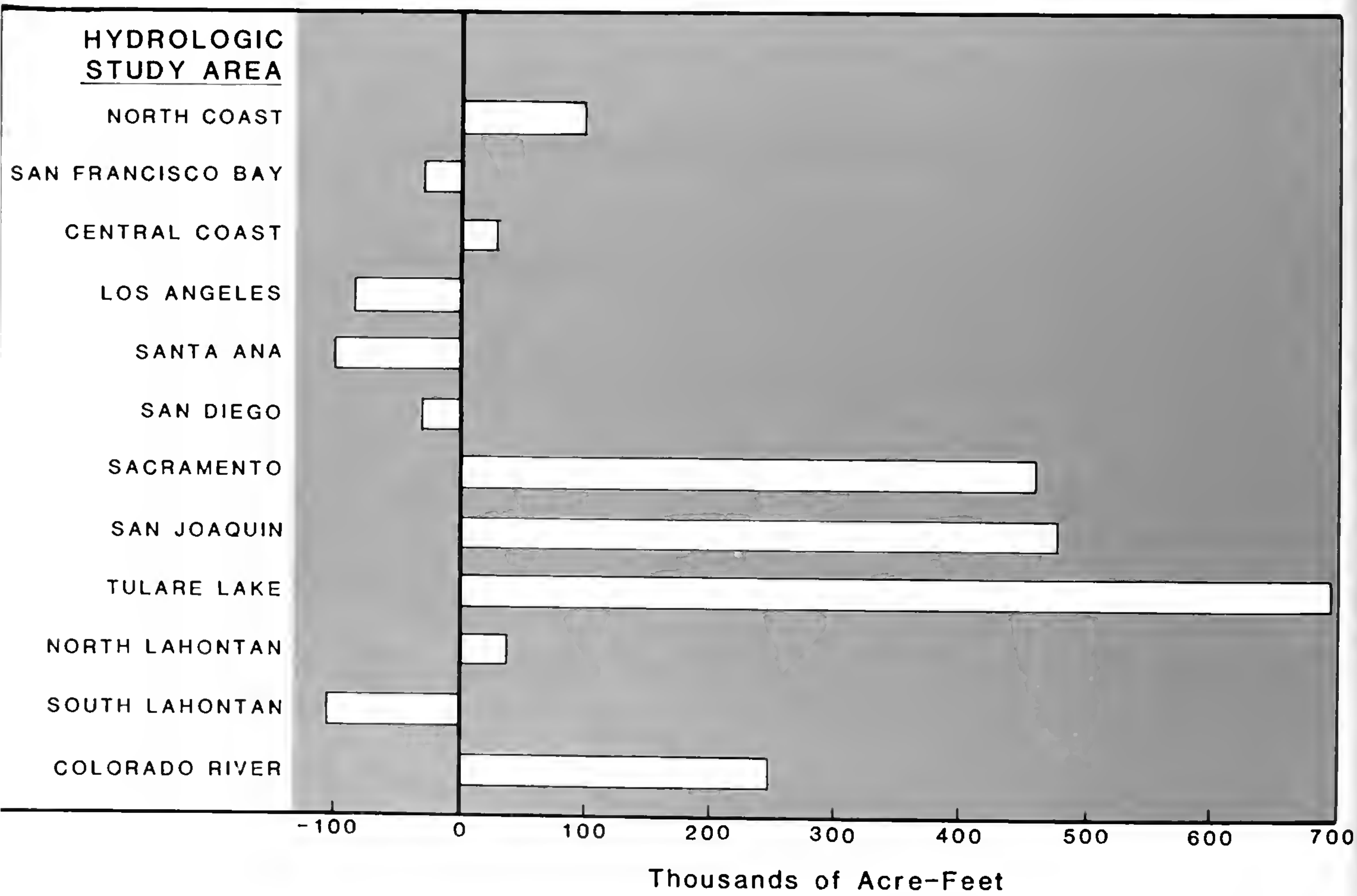
TABLE 37

AGRICULTURAL APPLIED WATER AND NET WATER USE BY HYDROLOGIC STUDY AREA BY DECADES TO 2010

(In 1,000s of acre-feet)

Year	NC	SF	CC	LA	SA	SD	SB	SJ	TL	NL	SL	CR	TOTAL
APPLIED WATER													
1980	821	121	1,189	348	412	228	9,223	7,474	11,424	442	493	3,460	35,635
1990	900	110	1,240	310	360	220	9,350	7,470	11,390	470	410	3,590	35,820
2000	910	100	1,230	270	310	200	9,000	7,510	11,390	470	350	3,730	35,470
2010	930	90	1,200	230	260	190	9,070	7,680	11,540	480	280	3,700	35,650
NET WATER USE													
1980	714	121	902	276	320	198	6,682	5,892	7,781	387	338	3,434	27,045
1990	780	110	940	250	290	190	7,030	6,050	7,955	410	300	3,560	27,865
2000	790	100	940	220	250	180	7,010	6,160	8,185	410	270	3,700	28,215
2010	810	90	930	190	220	170	7,140	6,370	8,475	420	230	3,680	28,725
CHANGE IN NET WATER USE													
1980 to 2010	+95	−30	+30	−85	−100	−30	+460	+480	+690	+35	−110	+245	+1,680

Figure 42. CHANGE IN AGRICULTURAL NET WATER USE BY HSA 1980 TO 2010



Urban Water Use

Projections of urban applied water are based on estimates of future population and the per capita applied water. Estimates of urban net water use are obtained from a hydrologic balance analysis, including consideration of applied water, water reuse, total evapotranspiration of applied water, irrecoverable losses, and outflow. California's population is expected to continue growing substantially; because of water conservation and other factors, however, per capita applied water is not expected to increase as rapidly as it has in the past. Rather, it will tend to level off in many areas, and in some will be decreasing by 2010. Present projections indicate that, by 2010, total statewide urban net water use will increase by nearly 40 percent, from the current level of 5.0 million acre-feet to 6.8 million acre-feet per year.

Population Projections

According to a policy adopted by the Governor in 1978[7], State funding of capital projects must be based on the regional population projections developed by Councils of Governments (COGs) that have been approved by the State Office of Planning and Research. Further, to be approved, these regional projections cannot exceed the regional projections prepared by the State Department of Finance (DOF). For the counties not covered by COG projections, the DOF projections are to be used. Later in 1978, the Governor extended his policy by ordering that all policies, actions, and programs conform to these requirements.

When the 1980 census figures for the State became available, they showed that the existing population projections for 1980 were lower than actual population in many parts of California. In some counties, even the projections for 1985 and 1990 fell below the actual 1980 census results. The DOF subsequently issued a set of interim population projections for counties, extending them to 1990, based on the 1980 census. The Department of Water Resources further extended these projections to 2010, using the same procedures DOF used for 1990. Revised COG projections were not available in time for the analyses used in this report.

The rates of both natural increase (births minus deaths) and migration have changed, but the effect of both on population growth is upward. In the case of natural increase, the decline in fertility rates during the 1960s and into the 1970s was one of the most striking recent demographic trends. Earlier reports in the Bulletin 160 series had assumed fertility rates of 2.5 to 3.1 children per woman of childbearing age. For this report, the current low rate of 2.1 was assumed to continue to 2010. Even so, natural increase accounts for more than half, or 5.8 million, the projected population growth of 10.6 million by 2010.

Net migration—the difference between in-migration and out-migration—has probably fluctuated more than has any other component of population change. Since World War II, the increase caused by net migration has ranged from slightly more than 100,000 to 350,000 per year. The trend since 1970 has been upward and, in the last few years, has averaged about 250,000 per year. Part of this increase reflects changes in migration policies. Since 1979, half the migration has originated in the United States and half has been of foreign origin. Projections of net migration for this report have been placed at 150,000 annually, toward the lower end of the historical range. Net migration accounts for nearly 5 million of the total population increase of 10.6 million expected over the next 30 years.

California's total projected population for 2010 is 34.4 million, which amounts to 12.5 percent of the projected national total. National and State projections by decade are tabulated below.

U. S. and California Population
1980 and Projected
(In millions)

Year	*U. S.*	*California*	*California as a Percent of U. S.*
1980	227.7	23.8	10.5
1990	243.5	27.9	11.5
2000	260.4	31.3	12.0
2010	275.3	34.4	12.5

About half the future increase in population in California is expected to be derived from births and half from in-migration.

[7] The guidelines for this policy are outlined in a report, *An Urban Strategy for California*, issued by the State Office of Planning and Research in 1978.

California's share of U. S. population is projected to increase nearly 20 percent over the 1980 level. The increases by decades are shown by Figure 43.

Population Distribution. The 1980 census population statistics by census tracts and enumeration districts were used to determine population in each Detailed Analysis Unit. Projections for DAUs were based on the projections by county prepared by the Department of Finance (to 1990) and the Department of Water Resources (1990 to 2010) and on information gained from local planning agencies and the regional Councils of Governments regarding the directions that future growth is most likely to take. Present and projected population figures by HSAs are summarized in Table 38.

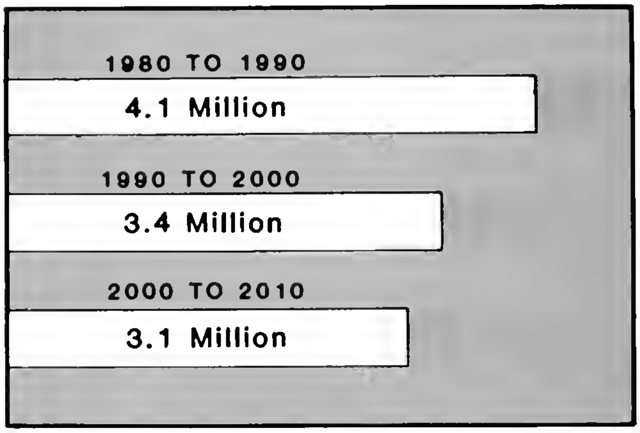
Taken as a whole, the urban areas in Southern California dominate the outlook, accounting for about 50 percent of total State growth. The population increase in the Santa Ana HSA, which encompasses most of Orange County and the western sections of San Bernardino and Riverside Counties, is expected to surpass that in any other region. Other major areas of growth, outside the South Coastal region, in decreasing order, are the Sacramento, San Francisco Bay, San Joaquin, and Tulare Lake HSAs.

Per Capita Applied Water Projections

The process for projecting per capita applied water involved two steps.

- First, the trends from about 1960 through 1975 (the year before the drought) were extrapolated to 2010, considering apparent and expected changes in some of the major influencing factors, excluding water conservation.

Figure 43. PROJECTED POPULATION INCREASE BY DECADES 1980-2010



- Then, the impact of specific water conservation actions from 1976 to 2010 were estimated and the extrapolated values adjusted downward accordingly. These two sets of values provided a basis for calculating future urban applied water, both with and without conservation.

Projection of Trends (Without Conservation). In nearly all urban areas of the State, per capita applied water through 1975 trended upward. In recent years, changes appear to have been occurring which, even without the specific water conservation actions that have either been implemented or been planned, would tend to slow the rate of increase. In some communities, this will actually cause per capita applied water to level off in the near future. Although climatic fluctuations commonly cause

TABLE 38

CALIFORNIA POPULATION BY HYDROLOGIC STUDY AREA BY DECADES TO 2010 (In thousands)

HSA	*1980*	*1990*	*2000*	*2010*	*Increase 1980–2010*	*Percent of State Increase, 1980–2010*
NC	459	570	660	760	300	3
SF	4,790	5,250	5,600	5,900	1,110	10
CC	1,005	1,190	1,340	1,490	480	5
LA	7,927	8,650	9,140	9,650	1,720	16
SA	2,974	3,790	4,430	5,060	2,090	20
SD	2,068	2,580	3,040	3,440	1,370	13
SB	1,674	2,200	2,590	2,930	1,260	12
SJ	1,014	1,330	1,630	1,910	900	8
TL	1,178	1,440	1,670	1,920	740	7
NL	61	80	100	120	60	–
SL	303	400	510	570	270	3
CR	320	430	540	630	310	3
STATE TOTAL	23,773	27,910	31,250	34,380	10,610[1]	100

[1] Statewide increase is 44 percent

per capita use to vary significantly from year to year, an important aspect of urban applied water is that fundamental long-term changes in average per capita values for a large metropolitan area usually occur slowly. This is because of the large established base of water use in the area. Except where water conservation measures are at work, or where water prices have risen markedly, long-term trends are not normally altered by changes in practice by individual water users. Rather, changes in average per capita applied water occur as a result of the increase in proportion of the population having higher (or lower) per capita rates. As an example, after World War II, suburban living became popular. Much of the housing development since then has typically had higher rates of use than the older-city type of development, primarily because of more extensive landscaping. Since about half of residential water use is for landscape irrigation, the increasing proportion of total population living in the suburbs compared to that living in the older city areas has contributed to the increasingly upward trend in average annual per capita applied water seen in the larger metropolitan areas.

Climate is another factor which has strongly influenced the change in the overall average per capita applied water value in the State's coastal metropolitan areas. Water use for landscapes is considerably greater in inland regions than along the coast. In both the San Francisco Bay area and the South Coastal region, most of the land near the ocean (typically cooler than inland areas) has already been developed. As the inland proportion of the total metropolitan area increases in comparison to the area influenced by the cooler ocean climate, the weighted average per capita applied water value increases.

The foregoing factors were considered in evaluating the impact of expected changes in other specific characteristics of water use, most of which should gradually slow the rate of increase in per capita applied water in most urban areas. In some cases, they may cause a leveling off and, eventually, a decrease. Some of them are:

- ***Housing Density.*** The relative proportion of people living in multi-unit housing and mobile homes is expected to increase. In addition, the average size of new single-family home lots is expected to continue to decrease. Both of these factors should reduce the average landscape area per capita for new development. This, in turn, would tend to reduce per capita applied water.
- ***Household Size.*** The average number of persons per household is expected to continue to decline slightly. This should tend to increase per capita applied water because certain residential water uses are relatively independent of household size. Among these uses are house cleaning, food preparation, clothes and dish washing (to some extent), landscape irrigation, swimming pool maintenance, and car washing.
- ***Increased Energy Conservation.*** Real energy costs are expected to continue rising. This will likely reduce the use of hot water, lowering per capita applied water.
- ***Water Prices.*** In recent years, water prices to consumers in many urban areas have risen faster than prices for other commodities. The prospect is for further increases, particularly in Southern California, where higher energy costs for pumping State Water Project water will have their greatest

In San Francisco, close-set homes, little irrigated landscaping, and a cool climate result in much lower residential per capita applied water than is typical of heavily landscaped suburbs in warm interior valleys, such as in Contra Costa County.

impact. As this occurs, it will tend to reduce per capita applied water.

The trend in per capita applied water through 1975 for each Detailed Analysis Unit was developed on the basis of historical annual delivery data provided by water service agencies and estimates of the population served. The trend for each area was extrapolated to 2010, considering the likely impacts in each area of the foregoing (and other) factors. The impact of water conservation actions was excluded. The result, generally, was a continuing decline in the rate of increase.

Results of Per Capita Applied Water Projections (Without Conservation). The 1980 and 2010 per capita applied water values (without conservation) for each Hydrologic Study Area are presented in Table 39. Values shown are weighted averages derived from the values and population of each of the many DAUs that make up each HSA. Average values for such large areas as HSAs are sometimes difficult to interpret because of the wide variation occurring within them. Some of the factors involved in the changes in per capita values projected without conservation are:

- ***North Coast HSA.*** The large amount of water used by the pulp and paper mills situated at Humboldt Bay, as a proportion of total urban water use, is responsible for the relatively high 1980 value for per capita applied water. This value is expected to drop 14 percent by 2010. Population is expected to grow, but water use by the pulp and paper mills is not expected to change.
- ***San Francisco Bay, Los Angeles, Santa Ana, and San Diego HSAs.*** By 2010, an even larger proportion of the population is expected to be living in warm inland areas than in the cooler coastal areas. The increase of 13 to 25 percent is due largely to this projected trend.
- ***Sacramento, San Joaquin, Tulare Lake, and North Lahontan HSAs.*** In contrast to the coastal metropolitan areas, climate-related factors will not be responsible for a change in average per capita values. Instead, these values will be influenced by some of the other factors, discussed earlier, that are expected to cause per capita applied water to level off and then, in most areas, to decrease.
- ***Central Coast HSA.*** Unlike the other coastal metropolitan areas, land is still available near the coast, where a large part of the population growth is expected to occur. Further, this area generally has a limited water supply, a condition that will tend to counteract the impact of any increases in population locating in the warmer inland areas.
- ***South Lahontan and Colorado River HSAs.*** The principal reason for projecting increases in these areas is the continued growth in tourism and similar part-time visitation that is expected. A large transient population tends to increase the values for per capita applied water because per capita values are derived by dividing total applied water by permanent population.

TABLE 39

PROJECTED CHANGE IN WEIGHTED AVERAGE PER CAPITA APPLIED WATER WITHOUT CONSERVATION STATEWIDE AND BY HYDROLOGIC STUDY AREA 1980 to 2010 (In acre-feet per person)

HSA	*1980*	*2010*	*Percent Change*
NC	0.336	0.289	−14
SF	0.201	0.229	14
CC	0.236	0.240	2
LA	0.208	0.239	15
SA	0.247	0.280	13
SD	0.188	0.235	25
SB	0.340	0.331	−3
SJ	0.398	0.389	−2
TL	0.361	0.376	4
NL	0.377	0.375	−1
SL	0.314	0.398	26
CR	0.372	0.435	17
STATEWIDE	0.242	0.274	13

Impacts of Expected Water Conservation on Per Capita Applied Water. For this report, urban water conservation is defined as any action deliberately undertaken to reduce the amount of water applied. This distinguishes water conservation impacts from the impacts of such factors as housing trends and family size. The extent to which water conservation is expected to be practiced in various parts of the State was estimated in several ways, depending on the characteristics of urban water use and its significance in an area compared to other water uses.

Where urban water use is a relatively small portion of an area's total applied water, projections of applied water "without conservation" were simply adjusted downward by 15 percent to obtain an estimate of applied water "with conservation." This level of conservation, which is about the same as that determined by detailed analysis for the major metropolitan areas, was assumed to be achieved by 2000 or 2010, depending on the area. In areas in which per capita water use is already low, a smaller percentage reduction was used.

Projections for the San Francisco Bay, Santa Ana, Los Angeles, and San Diego HSAs; and for San Luis Obispo and Santa Barbara Counties were made by first separating the quantity of urban applied water into the categories of use: interior residential, exterior residential, commercial and governmental, and industrial. The amount of conservation expected in

each category was calculated for the proportion of the population that would be affected at a particular point in time. These reductions were then added to obtain total water conservation on a per capita basis. The result was subtracted from the projection of per capita applied water "without conservation." The estimate of future per capita applied water, so derived, has been used to calculate the projections of future urban applied water presented in this report. In areas with exemplary conservation programs of one kind or another, applied water reductions were assumed to be achieved sooner than indicated in the list of assumed water conservation actions that follows. For example, in the San Francisco Bay area, where East Bay Municipal Utility District has pioneered in the detection and repair of leaks in water supply systems, the applied water reductions of 4 percent from this program were assumed to be achieved in 1982 rather than by 2000.

The conservation measures and actions considered in projecting water use reductions and the assumptions made on the rate of implementation were:

- ***Interior Residential Water Conservation.*** Toilet flushing is by far the largest component of interior water use, averaging about 35 gallons per person daily when a conventional toilet requiring 5 to 7 gallons per flush is used. State law now requires that all new dwellings have toilets using no more than 3.5 gallons. Accordingly, *the Department's projections of applied water reflect a reduction to account for the installation of low-water-using toilets in all new development.*

  Water use in existing toilets can be reduced by installing a displacement bag or bottle in the tank. More than three million bags and bottles have been distributed by water utilities and the Department of Water Resources since 1973. Surveys made after the devices were distributed indicate that about 25 percent of households install and retain them. These programs are a very cost-effective way of reducing applied water, and they will probably continue. *By 1990, all households with conventional toilets will have had an opportunity to install a displacement device, and it was assumed that 25 percent of the households will actually install and retain them.*

  In accordance with State plumbing regulations, *the Department's projections of applied water reflect a reduction resulting from the installation of low-flow faucets and showerheads in new development.*

  Shower flow restrictors for existing showerheads usually accompany toilet displacement bags in conservation device distribution programs. The installation rate of shower flow restrictors is generally lower than that for displacement bags—13 percent, rather than 25 percent. *By 1990, flow restrictors will have been distributed to all households in the State, and it was assumed that 13 percent of households will install and retain them.*

  Unlike toilets, which rarely require replacement, showerheads and faucets are replaced from time to time. *It was assumed that, by 2000, all showerheads and lavatory faucets used in the State will be the low-water-using kind.*

  Newer models of clothes washers and dishwashers use less water than those manufactured in the past. A study by the Department indicates that clothes washers manufactured in 1980 use about 15 percent less water than 1975 models; 1980 dishwashers use 25 percent less water than 1975 models. Consequently, appliances installed in new homes will use less water than do old appliances; also, as older appliances wear out, they will be replaced with models using less water. Although the average life of these appliances is ten years, *it was conservatively assumed that all pre-1975 clothes washers and dishwashers will be replaced by models using less water by 2000.*

  In most domestic water-heating systems, the pipes delivering hot water are not insulated. Consequently, the heated water cools while it is standing in the pipes, and householders must allow it to flow for a time until hot water is delivered from the faucet. *State regulations that took effect in 1982 require the insulation of hot water pipes in new residences. The projections of applied water reflect this.*

  Personal water use will also be affected by the many public education programs that have been introduced by the Department and public water utilities. In-school education programs have introduced water conservation to hundreds of thousands of school children. These and other programs have heightened the public's awareness of water conservation and the State's water problems. This is expected to lead to changes in water use habits, which should reduce interior water use over and above the reductions achieved as a result of water-saving plumbing fixtures and other measures. Based on experience in recent years, *it was assumed that, by 2000, interior use will be reduced by an additional 5 percent as a result of increased awareness of water conservation.*

- ***Exterior Residential Water Conservation.*** Nearly half of all residential water supplied in the State is used outdoors for watering lawns and gardens. Landscapes can easily be designed to require much less water than does traditional landscaping. Current trends suggest that an increased proportion of new landscapes will be low-water-using. Accordingly, *it was assumed that, by 2010, landscapes requiring 40 percent less applied*

On the average, about half the total residential water is used to irrigate landscaping. More care in watering could significantly reduce urban applied water in some communities.

water than do traditional landscapes will be installed on 50 percent of the new home lots.

The watering of traditional landscapes can also be improved. By avoiding excessive percolation, runoff, and evaporation, there may be about a 20-percent reduction of the water so applied. *It was assumed that, by 2000, water applied to existing landscapes will be reduced by 10 percent.*

- ***Commercial and Governmental Water Conservation.*** Water use by the commercial and governmental categories is much more diverse than residential water use and accounts for a much smaller proportion of total urban applied water. Consequently, the analyses of future water conservation and applied water by business and government were much less detailed than those for residential use. Nevertheless, reductions in applied water will probably also be achieved in these sectors. Parks, golf courses, and street and highway landscaping are being irrigated with greater efficiency than before; many new parks and highways are landscaped with low-water-using plants. Low-water-using showerheads and faucets will be installed in new commercial and public buildings. Low-flush toilets are required in all new hotels and motels, and legislation now under consideration would require low-flush toilets in all new commercial and public buildings. Clothes washing and dishwashing account for much commercial use, and commercial appliances are also becoming more efficient. Many businesses and government agencies began strong conservation programs during the drought. Some of these continue today. More opportunities for conservation will occur as older equipment is replaced and as new facilities are built. Accordingly, *it was assumed that, by 2000, commercial and governmental unit applied water will be 15 percent lower than would occur without conservation.*

Opportunities to reduce applied water also exist in the operation of municipal water systems, principally in the repair of leaks in the distribution system. The Department and the State Water

Resources Control Board are currently beginning a $1.9 million research and assistance program to reduce municipal water system leakage. By implementing leak detection and repair programs, water utilities could reduce such losses from the present average of about 10 percent of total deliveries to about 6 percent. *It was assumed that, by 2000, leak detection and repair would bring about a 4-percent reduction in applied water.*

- ***Industrial Water Conservation.*** Industrial water users began vigorous conservation efforts well before the 1976–1977 drought in an effort to reduce their waste water disposal fees and to respond to waste discharge regulations. The Federal Water Pollution Control Act Amendments of 1972 required that all firms discharging industrial waste to public waste water treatment plants repay all costs allocated to the treatment of their waste. In many cases, firms have reduced their use of water significantly by recycling and other means and have substantially reduced their discharges of waste, thus lowering their waste water discharge bills. As older equipment is replaced, even greater savings will be possible. *It was assumed that, by 2000, industrial applied water will be 15 percent lower than the historical unit rate of use.*

Reductions in 2010 Per Capita Use Due to Conservation. The total impact of all these conservation actions in terms of per capita applied water was estimated for each DAU and then, based upon the projected population in each DAU, the weighted average value for each HSA was calculated. These are presented in Table 40, which compares the "without conservation" and "with conservation" values for 2010. The impact of water conservation on the need for water supply is discussed in the last section of this chapter.

TABLE 40

EFFECTS OF WATER CONSERVATION ON WEIGHTED AVERAGE PER CAPITA APPLIED WATER IN 2010, STATEWIDE AND BY HYDROLOGIC STUDY AREA
(In acre-feet per person)

HSA	*Without Conservation*	*With Conservation*	*Percent Reduction Due To Conservation*
NC	0.289	0.259	−10
SF	0.229	0.197	−14
CC	0.240	0.215	−10
LA	0.239	0.202	−15
SA	0.280	0.233	−17
SD	0.235	0.195	−17
SB	0.331	0.286	−14
SJ	0.389	0.343	−12
TL	0.376	0.330	−12
NL	0.375	0.325	−13
SL	0.398	0.333	−16
CR	0.435	0.367	−16
STATEWIDE	0.274	0.235	−14

Manufacturing industries are expected to continue taking measures to reduce their fresh water requirements.

Urban Applied Water and Net Water Use—1980 and Projected

Projections of urban applied water were calculated by DAU from projected population and per capita applied water values. Estimates of quantities of excess applied water not available for reuse (including waste and storm drain water discharged to the ocean), together with calculated ETAW, formed the basis for estimating net water use.

Total urban applied water and related net water use by HSA for 1980, 1990, 2000, and 2010 are presented in Table 41. Urban net water use, statewide, is projected to increase by 1,860,000 acre-feet—from 4,978,000 acre-feet in 1980 to 6,840,000 acre-feet in 2010. Sixty percent of the projected increase is in the coastal metropolitan HSAs (San Francisco Bay, Central Coast, Los Angeles, Santa Ana, and San Diego). About 30 percent is in the Central Valley in the Sacramento, San Joaquin, and Tulare Lake HSAs.

According to these projections, the largest per decade increase in net use—692,000 acre-feet—will occur between 1980 and 1990. The increase will slow to only 535,000 acre-feet between 1990 and 2000 and then rise by 635,000 acre-feet between 2000 and 2010. The reason for the lesser increase between 1990 and 2000 is the interaction between projections of population trends and the effect of water conservation measures. As shown in Figure 43, projected population increases are most rapid between 1980 and 1990 and then tend to level off. Water conservation measures are projected to have their greatest impact between 1990 and 2000. After 2000, the effect of water conservation on per capita urban use is projected to remain at substantially the same level.

The distribution among HSAs of increases in urban net water use from 1980 to 2010 is shown in Figure 44. The largest increase in net water use is projected to take place in the Santa Ana HSA, where the greatest population growth is expected to occur. The three South Coast HSAs (Santa Ana, Los Angeles, and San Diego) are projected to account for 860,000 acre-feet out of a total increase for the State of 1,860,000 acre-feet. Also expected to show relatively large increases, in declining order, are the Sacramento, San Francisco Bay, and San Joaquin HSAs. The smallest increases, reflecting the small change in population that is projected, should take place in the North Lahontan HSA and the North Coast HSA.

Fish, Wildlife, Recreation, and Related Water Management Needs

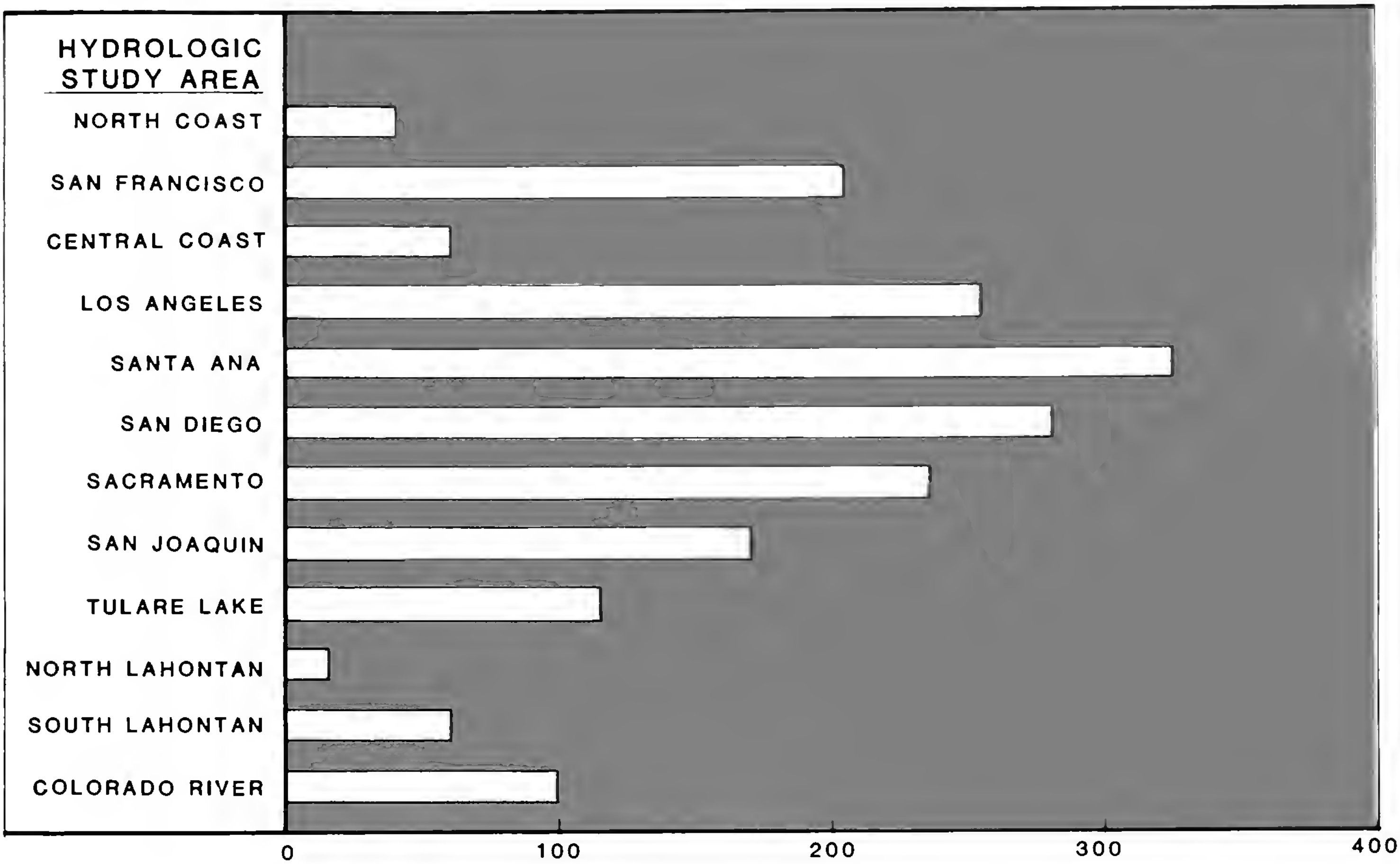
The public's interest in fresh-water recreation, fisheries, and wildlife has increased markedly in recent years and is expected to continue to grow. This growth will come not only from the increases in population, but also from greater per capita participation in specific water-related leisure pursuits and greater concern for protection and enhancing fisheries and wildlife.

In this chapter, data have been shown by decade to 2010 wherever possible. However, this section differs somewhat because projections for the entire 1980–2010 period were not always obtainable. Data and projections for fish and wildlife originated with the Department of Fish and Game, and, for water-related recreation, with the Department of Parks and Recreation. Projections for angler participation days were available only to 1990. No projections were available for sales of angling and hunting licenses, but some assumptions are presented in the text regarding trends that might be expected to occur. Projections for water-related recreation extend only to 2000.

TABLE 41
URBAN APPLIED WATER AND NET WATER USE BY HYDROLOGIC STUDY AREA BY DECADES TO 2010
(In 1,000s of acre-feet)

Year	*NC*	*SF*	*CC*	*LA*	*SA*	*SD*	*SB*	*SJ*	*TL*	*NL*	*SL*	*CR*	*TOTAL*
APPLIED WATER													
1980	153	967	231	1,654	734	389	570	403	425	23	95	118	5,762
1990	170	1,050	270	1,760	900	480	670	490	500	30	120	160	6,600
2000	180	1,090	290	1,830	1,030	580	750	570	550	35	160	200	7,265
2010	200	1,170	320	1,950	1,180	670	830	660	630	40	190	230	8,070
NET WATER USE													
1980	151	967	188	1,534	586	389	493	249	236	23	60	102	4,978
1990	170	1,050	210	1,630	710	480	590	310	280	30	80	130	5,670
2000	180	1,090	230	1,680	800	580	660	360	310	35	110	170	6,205
2010	190	1,170	250	1,790	910	670	730	420	350	40	120	200	6,840
CHANGE IN NET WATER USE													
1980 to 2010	+40	+205	+60	+255	+325	+280	+235	+170	+115	+15	+60	+100	+1,860

Figure 44. INCREASE IN URBAN NET WATER USE BY HSA 1980 TO 2010



Sport fishing will probably increase in popularity.

TABLE 42

ANGLING LICENSE SALES IN CALIFORNIA
1950 to 1980

Year	Sales per 100 persons	Year	Sales per 100 persons	Year	Sales per 100 persons
1950	9.2	1960	9.3	1970	11.6
1951	9.1	1961	9.1	1971	11.2
1952	9.4	1962	9.4	1972	10.6
1953	9.8	1963	9.7	1973	11.2
1954	9.9	1964	9.8	1974	11.2
1955	10.0	1965	10.0	1975	10.6
1956	10.2	1966	10.5	1976	10.2
1957	10.1	1967	10.4	1977	9.7
1958	9.4	1968	11.1	1978	10.4
1959	9.6	1969	11.0	1979	10.2
				1980	10.7

Source California Department of Fish and Game *Draft Fish and Wildlife Plan*, 1981

Future Use of Fishery Resources

Sport fishing in California is increasing, due not only to the growth in population but also to a greater per capita participation. Table 42 shows the numbers of angling licenses sold in California from 1950 through 1980. The most significant feature of these data is that angling licenses per 100 persons averaged about 9.7 during the 1950s and about 10.7 during the 1970s. Although this growth did not occur without ups and downs, it firmly establishes sport fishing as a progressively stronger activity in California. The need to support the fishery resources that sustain it is expected to continue.

Sport fishing in California includes angling for trout, marine fish, warmwater fish, and anadromous (migratory) fish. Angler use estimates for 1980 and projections for 1990 are shown in Table 43, which also shows individual species and types of fishing access. The projections to 1990 are in proportion to the estimate of future statewide population growth, with the same per capita participation rates that were observed in 1980.

Speculation is possible, based on experience, concerning negative influences on the future of fish populations and sport fishing. The pressure placed on the resource by increasing numbers of anglers will be intensified by conversion of land and water to other uses. The latter will tend to impair fishery habitat by degrading water quality. Public access to fishable waters may also be impeded. However, several influences are at work to benefit the resource. The Department of Fish and Game (DFG) has a body of law and the budgetary support necessary to make it a strong force in the protection of fishery resources. Many private organizations are also increasing their support for preservation of fish and fish habitat.

Despite the growing use of water resources, both instream and reservoir fisheries will probably receive increasing protection in water rights permits and energy development licenses. As these permits and licenses are periodically revised or renewed, conditions for fisheries may be bettered over those of original projects.

TABLE 43

ESTIMATED ANGLER PARTICIPATION IN CALIFORNIA BY TYPE OF FISHING
1980 and 1990
(In millions of angler-days)

Activity	1980	1990
Trout Fishing		
Cultured trout	7.0	8.2
Wild trout	6.1	7.2
Privately stocked trout	1.9	2.3
Total	15.0	17.7
Marine Fishing		
Piers	6.1	7.2
Shore	3.8	4.5
Private boats	1.8	2.1
Party boats	1.0	1.1
Other	0.3	0.4
Total	13.0	15.3
Warmwater Fishing		
Catfish	3.1	3.6
Bass	2.9	3.4
Sunfish	2.8	3.3
Total	8.8	10.3
Anadromous Fishing		
Striped bass (inland and marine)	2.0	2.4
Ocean salmon	1.0	1.2
Inland salmon	0.4	0.5
Steelhead	0.3	0.3
Sturgeon	0.1	0.1
American Shad	0.1	0.1
Total	3.9	4.6
TOTAL, ALL TYPES	40.7	47.9

Source California Department of Fish and Game, *Draft Fish and Wildlife Plan*, 1981

Future Use of Wildlife Resources

The principal habitat for many wildlife species is closely associated with streams, lakes, or marshes, and for some, their continuing existence depends entirely on the presence of wetlands or bodies of water. California's wildlife is diverse and widely distributed. Many species are classified as game and are hunted under strictly regulated conditions. Many other birds and animals are classified as nongame species and are not hunted, although many of these (along with game species) are of intense interest to many people and provide significant enjoyment, education, and other values.

Although hunting is not expected to increase much, bird-watching, wildlife photography, and similor nonoppropriative uses of wildlife should grow substontiolly.

TABLE 44

HUNTING LICENSE SALES IN CALIFORNIA
1950 to 1980

Year	Sales per 100 persons	Year	Sales per 100 persons	Year	Sales per 100 persons
1950	4.6	1960	4.0	1970	3.8
1951	4.8	1961	3.9	1971	3.5
1952	5.1	1962	3.8	1972	3.1
1953	5.1	1963	3.7	1973	3.2
1954	5.0	1964	3.8	1974	3.1
1955	5.0	1965	3.8	1975	2.9
1956	4.9	1966	3.8	1976	2.6
1957	4.6	1967	4.0	1977	2.6
1958	4.1	1968	3.9	1978	2.3
1959	4.0	1969	3.8	1979	2.2
				1980	2.3

Source: California Department of Fish and Game, *Draft Fish and Wildlife Plan*, 1981.

Unlike fishing, the sport of hunting is declining in relative popularity. As shown in Table 44, the sale of hunting licenses dropped between 1950 to 1980 from about 5.0 to nearly 2.0 per 100 persons. DFG expects this percentage participation rate to continue to decline slowly, although total number of hunter-days will increase due to population growth.

The use and enjoyment of wildlife for purposes other than hunting (referred to by DFG as nonappropriative use) is growing rapidly. Bird watching, wildlife photography, and similar activities are attracting numerous participants; and, although no statewide studies have been conducted to document the level of such use, other evidence indicates growing popularity. According to DFG estimates, nonappropriative uses of fish and wildlife in California in 1980 amounted to 48 million days of participation; such use is projected to reach over 70 million by 1990. These figures can be compared with their estimate of 7.4 million hunter-days in 1980 and 9.5 million hunter-days projected by 1990. Maintenance of wildlife habitat will continue to be an important consideration in preparing and implementing water management plans.

Future Water-Associated Recreation

According to data developed by the Department of Parks and Recreation (DPR), participation in water-related recreation in California for some time has been nearly 90 days per person annually, with some activities becoming more popular and some less.

A statewide analysis of recreation needs by DPR, which included data on 55 types of water-associated recreation, indicated that participation in most of these activities was on the rise. The study estimated the extent of use in these categories in terms of per capita participation-days and projected these figures to 2000. Table 45 presents the projections for the kinds of recreation activities that are clearly associated with fresh-water streams and lakes and fresh and brackish water marshes. Sailing (including salt-water sailing) is projected to increase 25 percent. If this occurs, total participation-days in 2000 will be 15.5 million, compared to 12.5 million days with no increase in per capita participation. "Other boating"—primarily rafting—is expected to increase about 20 percent; power boating should also increase. While the per capita rates for lake and stream fishing and fresh-water swimming are projected to rise slightly, water skiing and waterfowl hunting are expected to decline. Overall, the projections show a 5-percent increase in participation per person, which, coupled with the expected population growth in California, will result in an increase of about 65 million participation-days for all water-associated recreation by 2010 (Figure 45).

TABLE 45

SELECTED WATER-ASSOCIATED RECREATION ACTIVITIES IN CALIFORNIA [1]
1980 and 2000
(In per capita participation-days)

Activity	1980	2000
Lake fishing	0.907	0.930
Stream fishing	0.706	0.732
Fresh-water swimming	1.137	1.199
Water skiing	0.727	0.711
Power boating	0.522	0.563
Sailing	0.401	0.496
Other boating (including rafting)	0.340	0.398
Waterfowl hunting	0.072	0.064
TOTAL	4.812	5.093

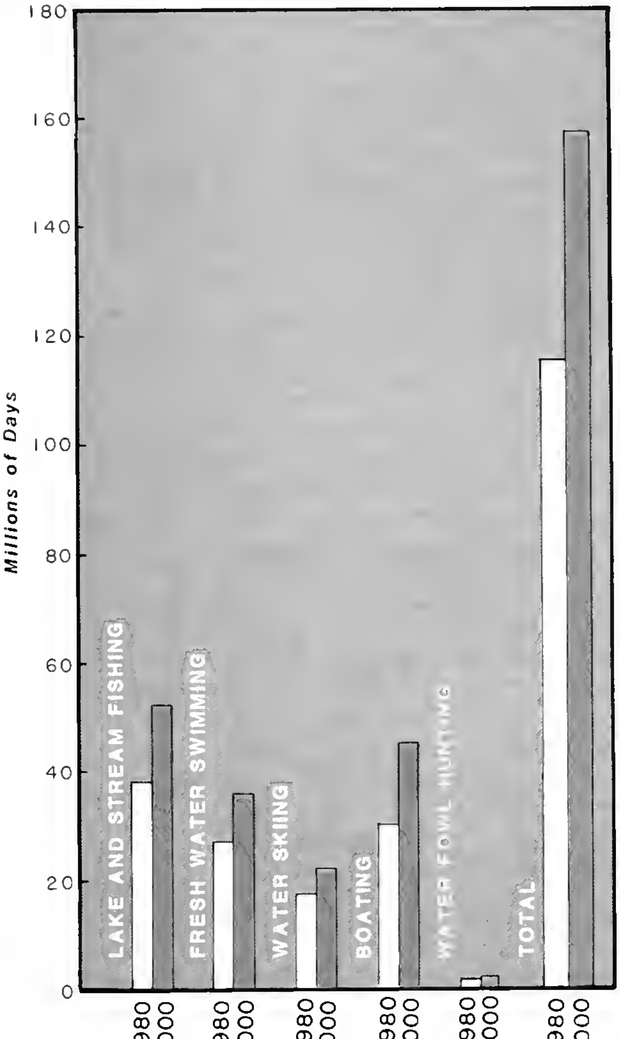
Source: California Department of Parks and Recreation, Division of Planning, *Statewide Recreation Needs Analysis*, December 1981.

[1] Selected from a study of 55 activities by the Department of Parks and Recreation to include those which directly involve the use of fresh-water streams and lakes or bodies of brackish water.

Future Offstream Water Use for Fish, Wildlife, and Fresh-Water Recreation

Offstream water use refers to uses supported by

Figure 45. PARTICIPATION-DAYS IN VARIOUS WATER-ASSOCIATED RECREATION ACTIVITIES 1980 AND 2000



water diverted from a stream. The 1980 and projected estimates of offstream water use for wildlife management areas and for parks lying outside urban areas are presented in Tables 46 and 47. (Water use by parks within urban areas is included in the urban water use figures.)

For wildlife management areas, no significant increases between 1980 and 2010 are expected. The only increase—15,000 acre-feet by 1990—is projected in the North Coast HSA, where expansion of wildlife management areas is expected. No other such changes are projected in any part of the State by 2010.

For nonurban public parks, water use is expected to more than double between 1980 and 2010—from 43,000 acre-feet in 1980 to 100,000 acre-feet in 2010. Of the total increase of 57,000 acre-feet, 37,000 acre-feet is projected to occur in the first decade. The greatest increase in any HSA in any one decade—11,000 acre-feet—is expected to take place between 1980 and 1990 in the South Lahontan HSA. About half that increase is related to the State Water Project. While only a nominal increase should occur in most of the HSAs, three of them—Los Angeles, Santa Ana, and South Lahontan—account for 36,000 acre-feet of the total increase of 57,000 acre-feet by 2010.

Future Protection and Enhancement of Instream Water Uses

Determination of instream flows needed to support the fish population and instream recreation requires a case-by-case assessment. This has not yet been performed on a statewide or regional basis. New techniques have been developed within the last 10 years to better determine the amount of water needed in a stream or river to maintain fish and wildlife at suitable levels. The U. S. Fish and Wildlife Service's "Instream Flow Incremental Methodology" and other techniques should allow more realistic determination of instream flow needs and establishment of adequate flows below water diversions and hydropower projects.

A bill relating to streamflow protection standards was enacted by the Legislature in 1982. Assembly Bill 3493 (Chapter 1478 of the Public Resources Code) requires the Director of the Department of Fish and Game to identify and list the streams and watercourses in the State for which minimum flow levels need to be established to ensure the continued viability of stream-related fish and wildlife resources. The bill authorizes the Director of DFG to submit the list to SWRCB for consideration on any application for permits and licenses to appropriate water.

Water Use For Energy Production

Comparatively small increases in water use are projected for power plant cooling and enhanced oil recovery. In some cases, however, such use occurs in water-deficient areas where it has local significance. Where this happens, fresh-water use is expected to be minimized through the use of treated waste water, sea water, and/or water that may be produced by the oil recovery process.

Water Use for Power Plant Cooling

For almost a decade, the California Energy Commission (CEC) has periodically revised its forecasts of electricity demands, each time providing a lower estimate than before. Large price increases for electrical energy, coupled with private and public conservation actions, have contributed heavily to the downward direction of these forecasts. Moreover, a

TABLE 46
WATER USE FOR WILDLIFE MANAGEMENT AREAS BY HYDROLOGIC STUDY AREA BY DECADES TO 2010
(In 1,000s of acre-feet)

Year	NC	SF	CC	LA	SA	SD	SB	SJ	TL	NL	SL	CR	TOTAL
APPLIED WATER													
1980	260	100	–	7	–	5	167	86	45	10	3	17	700
1990, 2000, 2010	270	100	–	7	–	5	167	86	45	10	3	17	710
NET WATER USE													
1980	215	94	–	7	–	5	157	64	31	10	3	17	603
1990, 2000, 2010	230	94	–	7	–	5	157	64	31	10	3	17	618

TABLE 47
WATER USE IN NONURBAN PUBLIC PARKS BY HYDROLOGIC STUDY AREA BY DECADES TO 2010
(In 1,000s of acre-feet)

Year	NC	SF	CC	LA	SA	SD	SB	SJ	TL	NL	SL	CR	TOTAL
APPLIED WATER AND NET WATER USE [1]													
1980	1	2	2	1	2	2	3	10	7	1	9	3	43
1990	1	3	3	7	8	3	5	14	10	1	20	5	80
2000	1	3	5	11	9	3	5	14	10	1	21	6	89
2010	2	3	5	14	10	4	5	14	11	2	24	6	100
CHANGE IN NET WATER USE													
1980 to 2010	+1	+1	+3	+13	+8	+2	+2	+4	+4	+1	+15	+3	+57

[1] Applied water was assumed to equal net water use

This reservoir at Rancho Seco nuclear powerplant near Sacramento provides both recreation and water for powerplant cooling.

different mix among electrical power-producing facilities has resulted in more modest projections of water requirements for cooling. This is reflected in Table 48, which presents estimates of fresh-water needs for power plant cooling by HSA, based on the CEC's latest forecasts of electricity demand.

The projections are in keeping with policies adopted by both the Department of Water Resources and the State Water Resources Control Board. In effect, water for power plant cooling should be obtained in the following order of priority: (1) waste water being discharged into the ocean; (2) ocean water; (3) brackish water from irrigation return flow; (4) inland waste water having low amounts of total dissolved solids; and (5) other inland water. Where the State has jurisdiction, the use of fresh inland water for cooling will be approved only when other sources are insufficient in quantity and/or quality or economically unsound.

The largest increase, amounting to more than half the additional statewide needs of 69,000 acre-feet, is the 40,000 acre-feet expected to occur in the Colorado River HSA, using reclaimed brackish drain water. Other significant increases should occur in the San Francisco Bay and South Lahontan HSAs. The current use of 8,000 acre-feet in the Santa Ana HSA will be eliminated by the retirement of existing oil/gas-fired plants in an effort to improve air quality.

Enhanced Oil Recovery

Enhanced oil recovery, which includes water flooding, thermal stimulation, and chemical stimulation, is used to extend the life of old oil fields and facilitate extraction of heavy oils. While water flooding and thermal methods have been used on a commercial scale for some time in California, chemical methods are projected to be used commercially in the near future, especially in the coastal areas. The water requirements associated with these methods will continue to be met by production water (water produced along with the oil), sea water, treated waste water from both urban and agricultural sources, and fresh water. Projected water requirements for enhanced oil recovery are summarized in Table 49.

Water is used for enhanced oil recovery in only four HSAs—Tulare Lake, Los Angeles, Central Coast, and Santa Ana. Total water use is projected to in-

TABLE 48

WATER USE FOR POWER PLANT COOLING BY HYDROLOGIC STUDY AREA BY DECADES TO 2010 (In 1,000s of acre-feet)

Year	*NC*	*SF*	*CC*	*LA*	*SA*	*SD*	*SB*	*SJ*	*TL*	*NL*	*SL*	*CR*	*TOTAL*
APPLIED WATER AND NET WATER USE[1]													
1980	–	6	–	5	8	–	–	15	3	–	2	3	42
1990	–	2	–	1	1	–	–	20	–	–	6	19	49
2000	–	17	–	2	–	–	2	20	–	1	16	31	89
2010	–	17	–	2	–	–	2	20	–	1	26	43	111
CHANGE IN NET WATER USE													
1980 to 2010	–	+11	–	−3	−8	–	+2	+5	−3	+1	+24	+40	+69

[1] Applied water was assumed to equal net water use

TABLE 49

WATER USE FOR ENHANCED OIL RECOVERY[1] BY HYDROLOGIC STUDY AREA BY DECADES TO 2010 (In 1,000s of acre-feet)

	1980		*1990*		*2000*		*2010*		*1980 to 2010 Change in Fresh Water Use*
HSA	*Total*	*Fresh*	*Total*	*Fresh*	*Total*	*Fresh*	*Total*	*Fresh*	
TL	63	7	191	25	181	40	180	40	+33
LA	95	2	210	32	122	24	82	16	+14
CC	15	7	65	15	59	15	47	12	+5
SA	27	1	30	1	25	1	25	1	—
TOTAL	200	17	496	73	387	80	334	69	+52

[1] Applied water and net water use.

Water use for enhanced oil recovery is expected to show considerable growth, particularly in southern San Joaquin Valley.

crease from 200,000 acre-feet to 496,000 acre-feet per year by 1990, when maximum oil production will be attained, and then decline to 334,000 acre-feet by 2010 as oil production drops. For fresh-water use, the maximum amount of 80,000 acre-feet is projected to be reached by 2000 and then decline by 2010 to 69,000 acre-feet. Total water use and the proportion of fresh to total water use from 1980 to 2010 vary for each of the four HSAs, but the Tulare Lake HSA is the only area projected to show a significant increase in use of fresh water during the entire 30-year period. In 2010, 40,000 acre-feet of the statewide total of 69,000 acre-feet of fresh water is projected to be used for enhanced oil recovery in the Tulare Lake HSA.

Summary of Applied Water and Net Water Use

Projections of annual water use in California—both applied and net—show a fairly constant increase to 2010 for most purposes. This trend is shown in Tables 50 through 53. Total change in net water use is shown in Figure 46.[8] As discussed earlier, net water use is the measure of water use that determines the adequacy of water supplies. Some of the significant findings regarding net water use include:

- Total net water use, statewide, is projected to increase between 1980 and 2010 by 3.5 million acre-feet from 33.8 million acre-feet to 37.3 million acre-feet. This is roughly a 10-percent increase over the 30-year period. To put this in perspective, the increase from 1972 to 1980 was 2.8 million acre-feet, a 9-percent increase in only eight years.

- Agriculture continues to be, by far, the major water user. Total net water use by agriculture is expected to increase by 1.65 million acre-feet between 1980 and 2010—a 6-percent increase. Agricultural water use, including its pro rata share of conveyance losses, was 83 percent of total net use in 1980 and is projected to be 79 percent in 2010.

- Total urban net water use, although significantly less than net water use by agriculture, is projected to increase by 1.86 million acre-feet between 1980 and 2010—a 38-percent increase—which exceeds the projected increase in agricultural use, both in percentage and quantity. Urban use, with its pro rata share of conveyance losses, will increase from 15 percent of total net use in 1980 to 19 percent in 2010.

- The only area of the State in which total net water use is projected to decline is the South Lahontan HSA. Although urban use will double, use by agriculture will drop to about two-thirds of the 1980 level.

- Both agricultural and urban net water use in the three Central Valley HSAs—Sacramento, San Joa-

[8] Total State net water use for 1960, 1967, and 1972 (presented in Bulletins 160-66, 160-70, and 160-74, respectively) and the 1980, 1990, 2000, and 2010 values presented in this report are shown in Chapter II, Figure 3

quin, and Tulare Lake—are projected to increase significantly (2.15 million acre-feet) over the 30-year period, with the total increase in net water use amounting to 2.24 million acre-feet. These three areas account for almost two-thirds of the total statewide increase of about 3.51 million acre-feet by 2010.

- The largest increase in net water use in any HSA between 1980 and 2010 is projected to take place in the Tulare Lake HSA. Total net use will increase by 842,000 acre-feet, with 694,000 acre-feet of this amount for agricultural use.
- The three South Coast HSAs—Los Angeles, Santa Ana, and San Diego—are expected to show an increase of 663,000 acre-feet of total net water use, or almost one-fifth of the statewide increase between 1980 and 2010. However, urban use is expected to increase by 861,000 acre-feet, while agricultural use is projected to decline by 214,000 acre-feet, reflecting the increasing urbanization of that region.

The effects of increases in net water use on specific water supplies and related water management needs for each HSA are discussed in Chapter V.

TABLE 50

TOTAL APPLIED WATER AND NET WATER USE BY HYDROLOGIC STUDY AREA

1980

(In 1,000s of acre-feet)

	NC	*SF*	*CC*	*LA*	*SA*	*SD*	*SB*	*SJ*	*TL*	*NL*	*SL*	*CR*	*TOTAL*
APPLIED WATER													
Agriculture	821	121	1,189	348	412	228	9,223	7,474	11,424	442	493	3,460	35,635
Urban	153	967	231	1,654	734	389	570	403	425	23	95	118	5,762
Wildlife [1]	260	100	—	7	—	5	167	86	45	10	3	17	700
Recreation [2]	1	2	2	1	2	2	3	10	7	1	9	3	43
Energy Production [3]	—	6	7	7	9	—	—	15	10	—	2	3	59
TOTAL	1,235	1,196	1,429	2,017	1,157	624	9,963	7,988	11,911	476	602	3,601	42,199
NET WATER USE													
Agriculture	714	121	902	276	320	198	6,682	5,892	7,781	387	338	3,434	27,045
Urban	151	967	188	1,534	586	389	493	249	236	23	60	102	4,978
Wildlife [1]	215	94	—	7	—	5	157	64	31	10	3	17	603
Recreation [2]	1	2	2	1	2	2	3	10	7	1	9	3	43
Energy Production [3]	—	6	7	7	9	—	—	15	10	—	2	3	59
Conveyance Losses	—	14	—	81	45	40	129	111	123	—	7	543	1,093
TOTAL	1,081	1,204	1,099	1,906	962	634	7,464	6,341	8,188	421	419	4,102	33,821

[1] Water used on public wildlife management areas
[2] Water used at nonurban public parks
[3] Water used for power plant cooling and for enhanced oil recovery

TABLE 51

TOTAL APPLIED WATER AND NET WATER USE BY HYDROLOGIC STUDY AREA

1990

(In 1,000s of acre-feet)

	NC	*SF*	*CC*	*LA*	*SA*	*SD*	*SB*	*SJ*	*TL*	*NL*	*SL*	*CR*	*TOTAL*
APPLIED WATER													
Agriculture	900	110	1,240	310	360	220	9,350	7,470	11,390	470	410	3,590	35,820
Urban	170	1,050	270	1,760	900	480	670	490	500	30	120	160	6,600
Wildlife [1]	270	100	—	5	—	5	170	85	45	10	5	15	710
Recreation [2]	—	5	5	5	10	5	5	15	10	—	20	5	85
Energy Production [3]	—	—	15	30	—	—	—	20	25	—	5	20	115
TOTAL	1,340	1,265	1,530	2,110	1,270	710	10,195	8,080	11,970	510	560	3,790	43,330
NET WATER USE													
Agriculture	780	110	940	250	290	190	7,030	6,050	7,955	410	300	3,560	27,865
Urban	170	1,050	210	1,630	710	480	590	310	280	30	80	130	5,670
Wildlife [1]	230	95	—	5	—	5	160	65	30	10	5	15	620
Recreation [2]	—	5	5	5	10	5	5	15	10	—	20	5	85
Energy Production [3]	—	—	15	30	—	—	—	20	25	—	5	20	115
Conveyance Losses	—	15	5	75	40	35	150	120	125	—	5	360	930
TOTAL	1,180	1,275	1,175	1,995	1,050	715	7,935	6,580	8,425	450	415	4,090	35,285

[1] Water used on public wildlife management areas
[2] Water used at nonurban public parks
[3] Water used for power plant cooling and for enhanced oil recovery

TABLE 52
TOTAL APPLIED WATER AND NET WATER USE BY HYDROLOGIC STUDY AREA
2000
(In 1,000s of acre-feet)

	NC	*SF*	*CC*	*LA*	*SA*	*SD*	*SB*	*SJ*	*TL*	*NL*	*SL*	*CR*	*TOTAL*
APPLIED WATER													
Agriculture	910	100	1,230	270	310	200	9,000	7,510	11,390	470	350	3,730	35,470
Urban	180	1,090	290	1,830	1,030	580	750	570	550	35	160	200	7,265
Wildlife [1]	270	100	—	5	—	5	170	85	45	10	5	15	710
Recreation [2]	—	5	5	10	10	5	5	15	10	—	20	5	90
Energy Production [3]	—	15	15	25	—	—	—	20	40	—	15	30	160
TOTAL	1,360	1,310	1,540	2,140	1,350	790	9,925	8,200	12,035	515	550	3,980	43,695
NET WATER USE													
Agriculture	790	100	940	220	250	180	7,010	6,160	8,185	410	270	3,700	28,215
Urban	180	1,090	230	1,680	800	580	660	360	310	35	110	170	6,205
Wildlife [1]	230	95	—	5	—	5	160	65	30	10	5	15	620
Recreation [2]	—	5	5	10	10	5	5	15	10	—	20	5	90
Energy Production [3]	—	15	15	25	—	—	—	20	40	—	15	30	160
Conveyance Losses	—	20	5	75	40	35	150	130	125	—	5	280	865
TOTAL	1,200	1,325	1,195	2,015	1,100	805	7,985	6,750	8,700	455	425	4,200	36,155

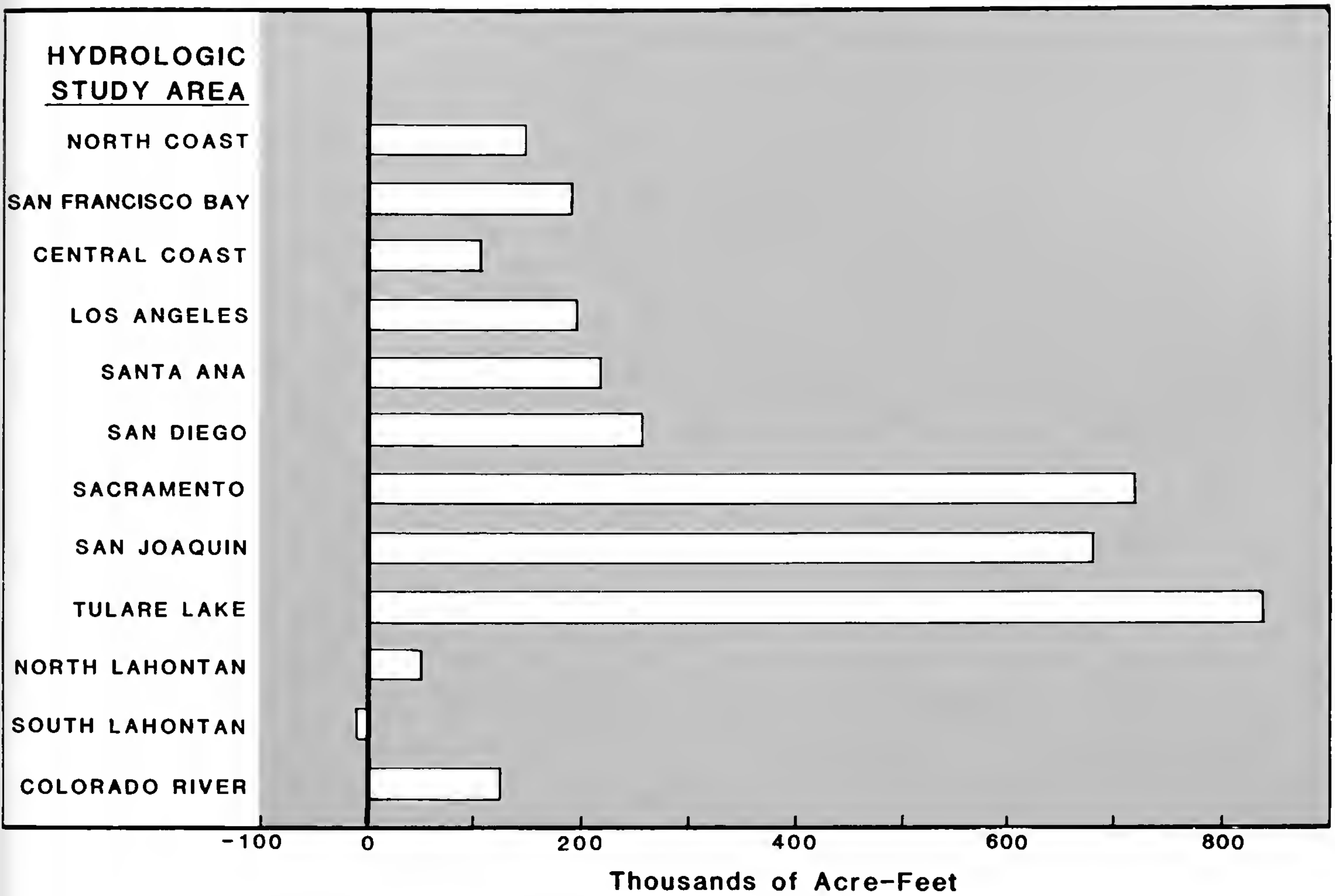
[1] Water used on public wildlife management areas.
[2] Water used at nonurban public parks.
[3] Water used for power plant cooling and for enhanced oil recovery

TABLE 53
TOTAL APPLIED WATER AND NET WATER USE BY HYDROLOGIC STUDY AREA
2010
(In 1,000s of acre-feet)

	NC	*SF*	*CC*	*LA*	*SA*	*SD*	*SB*	*SJ*	*TL*	*NL*	*SL*	*CR*	*TOTAL*
APPLIED WATER													
Agriculture	930	90	1,200	230	260	190	9,070	7,680	11,540	480	280	3,700	35,650
Urban	200	1,170	320	1,950	1,180	670	830	660	630	40	190	230	8,070
Wildlife [1]	270	100	—	5	—	5	170	85	45	10	5	15	710
Recreation [2]	—	5	5	15	10	5	5	15	10	—	25	5	100
Energy Production [3]	—	15	10	20	—	—	—	20	40	—	25	45	175
TOTAL	1,400	1,380	1,535	2,220	1,450	870	10,075	8,460	12,265	530	525	3,995	44,705
NET WATER USE													
Agriculture	810	90	930	190	220	170	7,140	6,370	8,475	420	230	3,680	28,725
Urban	190	1,170	250	1,790	910	670	730	420	350	40	120	200	6,840
Wildlife [1]	230	95	—	5	—	5	160	65	30	10	5	15	620
Recreation [2]	—	5	5	15	10	5	5	15	10	—	25	5	100
Energy Production [3]	—	15	10	20	—	—	—	20	40	—	25	45	175
Conveyance Losses	—	20	5	75	40	40	150	130	125	—	5	280	870
TOTAL	1,230	1,395	1,200	2,095	1,180	890	8,185	7,020	9,030	470	410	4,225	37,330

[1] Water used on public wildlife management areas.
[2] Water used at nonurban public parks.
[3] Water used for power plant cooling and for enhanced oil recovery.

Figure 46. CHANGE IN TOTAL NET WATER USE BY HSA 1980 TO 2010



Impacts of Water Conservation Assumptions

Projections of applied water reflect likely water conservation measures and actions, including increases in irrigation efficiency. The extent to which these actions actually create a savings in water supply depends upon how they influence net water use.

Net water use for a given study area will be reduced to the extent that water conservation measures and actions reduce crop or urban landscape ETAW, irrecoverable losses from distribution systems, or outflow from the area. In all cases, reductions in ETAW and irrecoverable losses are savings in water supply. The question of whether a saving in water supply is attained by reducing outflow from the area, however, depends on whether the outflow normally goes into an unusable source such as a salt sink (the ocean or saline ground water), supplies a downstream user, or accomplishes some special beneficial purpose, such as satisfying Delta outflow needs. In the latter two cases, there would be no water supply savings because the outflow fulfills a need that otherwise would have to be met from another source.

Although water conservation may not always achieve equivalent savings in water supply, significant energy savings may be achieved because repumping of excess applied irrigation water that percolates to ground water is reduced. Energy savings may also result from reduced delivery system pumping and treatment of water supplies and waste water.

Water Supply Savings from Water Conservation

For both the urban and the agricultural sectors, each DAU was examined to evaluate the reduction

in ETAW, irrecoverable losses from distribution systems, and outflow to a salt sink (or where otherwise unavailable for reuse) that would be achieved by the assumed water conservation actions, including increased irrigation efficiency. As discussed earlier, urban conservation included the impact of measures and actions taken from 1975 to 2010, while agricultural conservation was assumed to be any projected increase in irrigation efficiency and related measures after 1980.

In the urban sector, ETAW will be reduced because less water will be used to support landscape vegetation, principally reflecting increased use of drought-tolerant plants. For the agricultural sector, the ETAW reduction was calculated on the basis of assumptions regarding the extent to which drip irrigation will be used on young orchards and grapes. The ETAW reductions result from the wetting of a smaller soil area and, therefore, less evaporative loss. As the trees and vines mature and the root systems expand, however, the water savings potential becomes slight, if any.

Reduction in irrecoverable losses from distribution systems (seepage to saline ground water) was determined for the Imperial Valley, based upon the results of a study by the Department.[9]

The quantity of outflow to a salt sink or other unusable water body was determined through a hydrologic balance analysis relating net water use to net water supply.

Reductions in applied water and the related water supply savings in each HSA by 2010 are presented in Table 54. The urban water supply savings are about 50 percent higher than the agricultural savings. This is due primarily to the proximity of the major metropolitan areas to the ocean, where large portions of urban waste water and runoff (including storm drain flow) become outflow to the ocean. The remaining excess applied water percolates to ground water or is otherwise available for reuse. The urban water supply savings in inland areas is accomplished principally by reducing landscape evapotranspiration.

The very large reduction in applied water from increased irrigation efficiency in the Central Valley—nearly 3 million acre-feet—provides only 120,000 acre-feet in water supply savings because of the reuse of the excess applied water and the need to maintain specified outflows through the Delta. Excess irrigation water in the Central Valley, other than that consumptively used by native vegetation along drains and streams or in wetland areas, either percolates into ground water basins or drains back into rivers that flow to the Delta. During most of the irrigation season, Delta outflows are controlled to maintain water quality standards set by the State Water Resources Control Board. Under normal conditions, these required flows are such that any reduction in irrigation return flow to the Delta must be offset by increased reservoir releases (or by reducing export diversions).

[9] *Investigation Under California Water Code Section 275 of Use of Water by Imperial Irrigation District.* Department of Water Resources, December 1981.

TABLE 54

ANNUAL APPLIED WATER REDUCTIONS AND RELATED WATER SUPPLY SAVINGS IN 2010 RESULTING FROM WATER CONSERVATION[1] BY HYDROLOGIC STUDY AREA (In 1,000s of acre-feet)

	Urban		*Agricultural*		*TOTAL*	
HSA	*Applied Water Reductions*	*Water Supply Savings*	*Applied Water Reductions*	*Water Supply Savings*	*Applied Water Reductions*	*Water Supply Savings*
NC	25	20	5	—	30	20
SF	190	190	5	5	195	195
CC	25	25	40	5	65	30
LA	360	290	45	—	405	290
SA	240	160	40	—	280	160
SD	140	140	30	25	170	165
SB	130	30	1,480	—	1,610	30
SJ	85	25	580	10	665	35
TL	90	25	810	110	900	135
NL	5	—	35	—	40	—
SL	40	10	50	—	90	10
CR On-farm	45	40	360	340	405	380
CR Distribution system	—	—	—	150	—	150
TOTAL	1,375	955	3,480	645	4,855	1,600

[1] Reductions and savings from the level of water use that would occur without the projected conservation actions

The relatively large savings of 135,000 acre-feet projected for the Tulare Lake HSA primarily reflect reduced percolation of excess applied water to saline high water tables and moisture-deficient soils.[10]

A large water savings potential exists in the Colorado River HSA because excess applied water in the Imperial Valley and much of the Coachella Valley enters saline drains or saline ground water and cannot be reused. Where this occurs, any reduction in excess applied water represents a water savings. Substantial savings are also expected from distribution system improvements to reduce seepage to saline ground water and excess spillage to the Salton Sea.

The water conservation assumptions presented in this report represent what is now believed will likely occur. However, wider use of the conservation measures described in these assumptions or use of other water-saving measures could bring about even greater savings.

Energy Savings from Water Conservation in the Central Valley

A cursory estimate was made of the effect of a projected increase in irrigation efficiency on the use of electrical energy in the Central Valley. Part of the excess applied water in the valley runs off and is reused downstream or becomes part of the Delta outflow. The remainder percolates to ground water and is pumped and reused. With an increase in irrigation efficiency, less deep percolation of excess applied water would occur and less repumping would be necessary to satisfy applied water needs. This, along with estimates of pumping lifts and other factors affecting energy use, provide the basis for calculating the energy savings in 2010 due to agricultural water conservation.

Annual Energy Savings from Increased Irrigation Efficiency in the Central Valley in 2010

Hydrologic Study Areas	*Million kilowatthours*
Sacramento	20
San Joaquin	80
Tulare Lake	300
TOTAL	400

As would be expected, the projected reduction in electrical energy use is greatest in the Tulare Lake HSA, where most pumping lifts by 2010 are expected to range between 250 and 450 feet. Lesser savings are expected in the San Joaquin HSA, where lifts are expected to range between 100 and 200 feet. The savings in the Sacramento HSA would be even less, with lifts of 50 to 100 feet.

[10] Soils described as moisture-deficient are extraordinarily dry and have an unusually high capacity for retaining moisture. Water absorbed by moisture-deficient soils is "locked up" and unavailable to plants. Moreover, it does not percolate to a usable ground water source and thus represents a loss. These soils are confined primarily to a relatively small area along the southwestern edge of the valley floor in the Tulare Lake HSA.

CHAPTER V

PROJECTED USE OF WATER SUPPLIES TO 2010

This chapter analyzes the supply of water needed in California to satisfy the net water use projected to occur by 2010. It presents the situation related to existing and potential future surface water development, together with the role that ground water and reclaimed waste water are expected to play in meeting future needs. The chapter concludes with a summary of current and projected net water use and water supply and a discussion of water use and water supply conditions in each HSA.

The analysis shows that projected increases in urban and agricultural net water use will be supported by presently uncommitted Central Valley Project (CVP) supplies, reserve supplies of local projects, additional ground water overdraft, and increased waste water reuse. Except for the Cottonwood Creek Project, with yield allocated to nonfederal use, no new federal water supply reservoirs were assumed to be completed in the next 30 years. However, it was recognized that the Auburn and enlarged Shasta projects could be built within this period.

A similar situation exists with the State Water Project (SWP). Only relatively small additions to the yield of the SWP can definitely be identified at this time. The amount and timing of other water supply additions to the SWP are uncertain, although the possibility of substantially augmenting the yield of the SWP from new water supply facilities before 2000 is not likely because of the time required for authorization and construction. The Department of Water Resources has plans under way to select the best possible additional projects and schedule.

No new local projects were identified as definitely available by 2010 to meet projected needs. However, it was assumed that supplemental needs in the rapidly growing Sierra Nevada foothills could be provided for by such projects as the Upper South Fork American River Project and the Upper Stanislaus River Project. Local projects being considered in the Central Coast HSA would reduce the need to import CVP or SWP water to that area.

For the SWP, the yield from existing and planned facilities is inadequate to meet projected contractual commitments. Because the scheduling of future dependable supplies is uncertain, the potential shortfall is shown in the figures in this chapter as an SWP shortage. In most cases, the shortage could be offset by the use of ground water, thereby further increasing ground water overdraft.

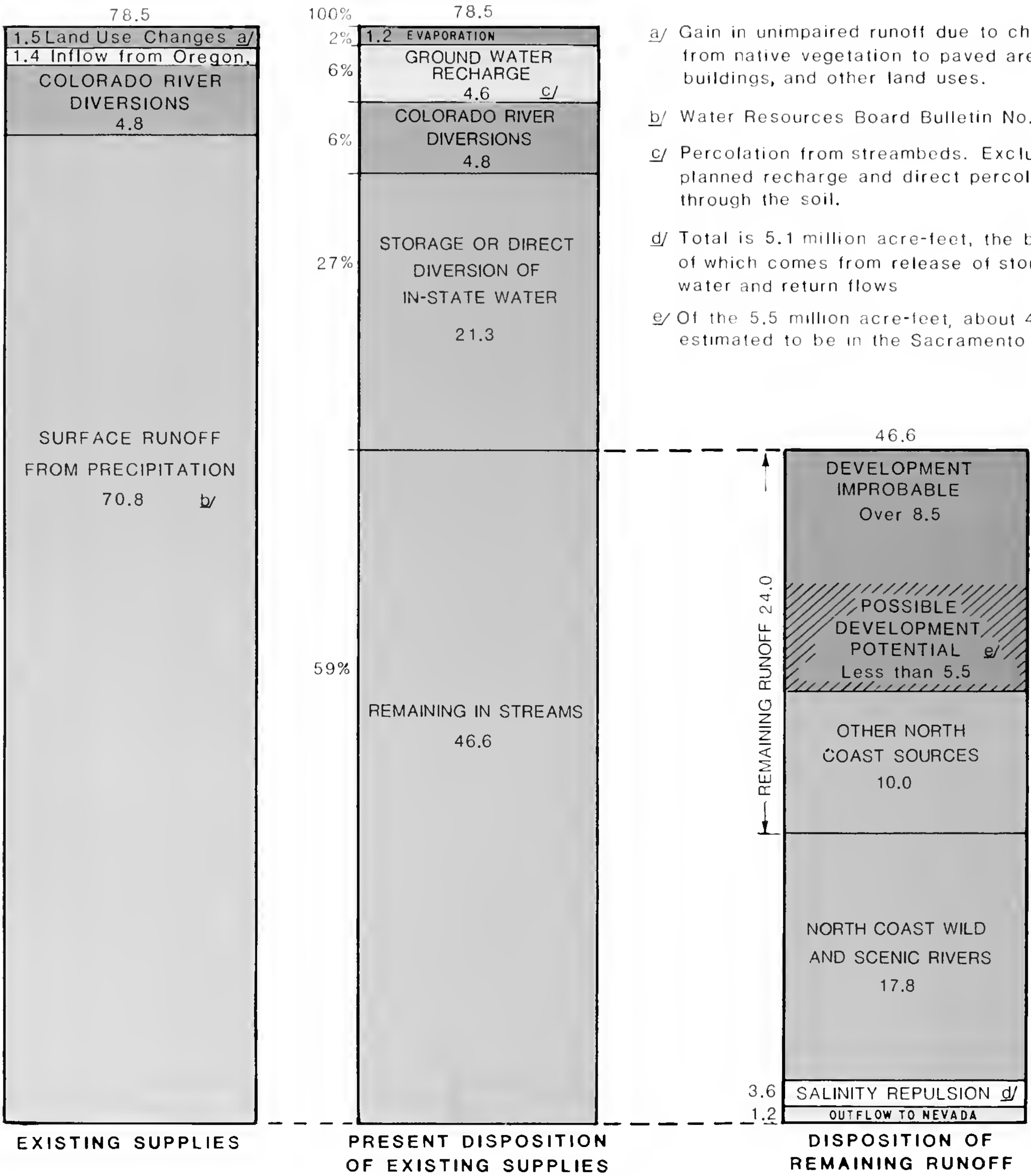
Only a substantial commitment to large-scale surface water storage and conveyance facilities would enable the major water supply problems in the State, including ground water overdraft, to be brought under control in the next 30 years. As noted above, except for Auburn Dam, which is in the final design stage but must be reauthorized by Congress, and the Cottonwood Creek project of the Corps of Engineers, it could be as much as 30 years before any other new major surface water supply projects—federal or State—can be put into operation. As a result, ground water overdraft in the San Joaquin Valley is projected to increase from 1.2 million acre-feet at the 1980 level of development to 2.4 million acre-feet and could go as high as 3.2 million acre-feet by 2010. The real increase, however, will depend on the extent to which reserve CVP supplies can be used in the Mid-Valley Canal service area or made available to the SWP and the extent to which SWP shortages will be offset by increased ground water use. Outside the San Joaquin Valley, an overall reduction in ground water overdraft is projected, with only the Sacramento and Colorado River HSAs showing any significant increase.

The other major problem area, the South Coastal region, where half the State's population lives, is faced with the potential of a shortage in dependable supplies occurring as early as the end of this decade. Identified supplies from the SWP in 1990 will be less than projected requirements by 215,000 acre-feet. By 2010, the shortage increases to 410,000 acre-feet. These potential shortages could occur, even though the use of reclaimed waste water savings from water conservation are expected to increase considerably. In the event of a prolonged drought such as occurred from 1928 to 1934, SWP supplies could not meet needs in this region. Extreme measures that could directly affect business, industry, and agriculture would be necessary to cope with such a situation. There is no assurance that surplus Colorado River supplies will be available to California, once the Cen-

Figure 47. REMAINING DEVELOPABLE SURFACE WATER IN CALIFORNIA

Long-Term Average-1980 Development Level

MILLIONS OF ACRE-FEET



a/ Gain in unimpaired runoff due to change from native vegetation to paved areas, buildings, and other land uses.

b/ Water Resources Board Bulletin No. 1, 1951

c/ Percolation from streambeds. Excludes planned recharge and direct percolation through the soil.

d/ Total is 5.1 million acre-feet, the balance of which comes from release of stored water and return flows

e/ Of the 5.5 million acre-feet, about 4.6 is estimated to be in the Sacramento HSA

tral Arizona Project is in operation. Ground water overdraft could provide emergency supplies, but this would require institutional changes in the operation of several adjudicated ground water basins.

Additional surface water supplies could be developed within the Sacramento Valley and could be used to meet or greatly reduce much of the need for supplemental supplies. The amount available and the projects being considered to develop this supply are presented in the following section of this chapter.

Surface Water Supplies

California's surface water available under the 1980 level of development averages 78,500,000 acre-feet per year. The sources and their present disposition are shown in Figure 47. The extent of present commitments on flows currently remaining in streams and the balance that has potential for development are shown by the right-hand bar. This distribution is in accordance with the basic assumption on water supply availability described in the preceding chapter. Out of the total of 24.0 million acre-feet of uncommitted remaining runoff, only 5.5 million acre-feet is considered developable. The reasons for this are both physical and economic. Likewise, North Coast flows amounting to about 10 million acre-feet are not considered to be a potential source of supply during the period of analysis.

Elsewhere in the State, the unregulated flow occurring in small coastal streams in the San Francisco Bay, Central Coast, Los Angeles, Santa Ana, and San Diego HSAs offer only limited opportunities for development. The same is true of runoff in the Southern California desert areas. In effect, it appears at this time that the opportunities for any significant further development of California's water resources are limited essentially to the Central Valley.

Present planning recognizes the need for equal consideration of instream and offstream uses of water. The center bar of Figure 47 shows the amount of water remaining in streams after allowance is made for imported water and present use. As depicted, 60 percent of California's surface water supplies presently remain in streams and rivers. Even if all the surface water estimated to be developable were eventually diverted, 52 percent of the State's surface water would remain in streams and rivers.

Additional surface water development has been planned or considered that would develop a portion of the 5.5 million acre-feet identified as "potentially developable." Some of these include development of local supplies to meet local needs and are described later in this chapter. The greatest need, however, exists in the San Joaquin, Tulare Lake, and South Coastal region HSAs and involve large-scale interbasin transfers. Consequently, further major surface water development probably can be accomplished only by the State through additions to the SWP and by the federal government, primarily through additions to the CVP.

State Water Project Supply

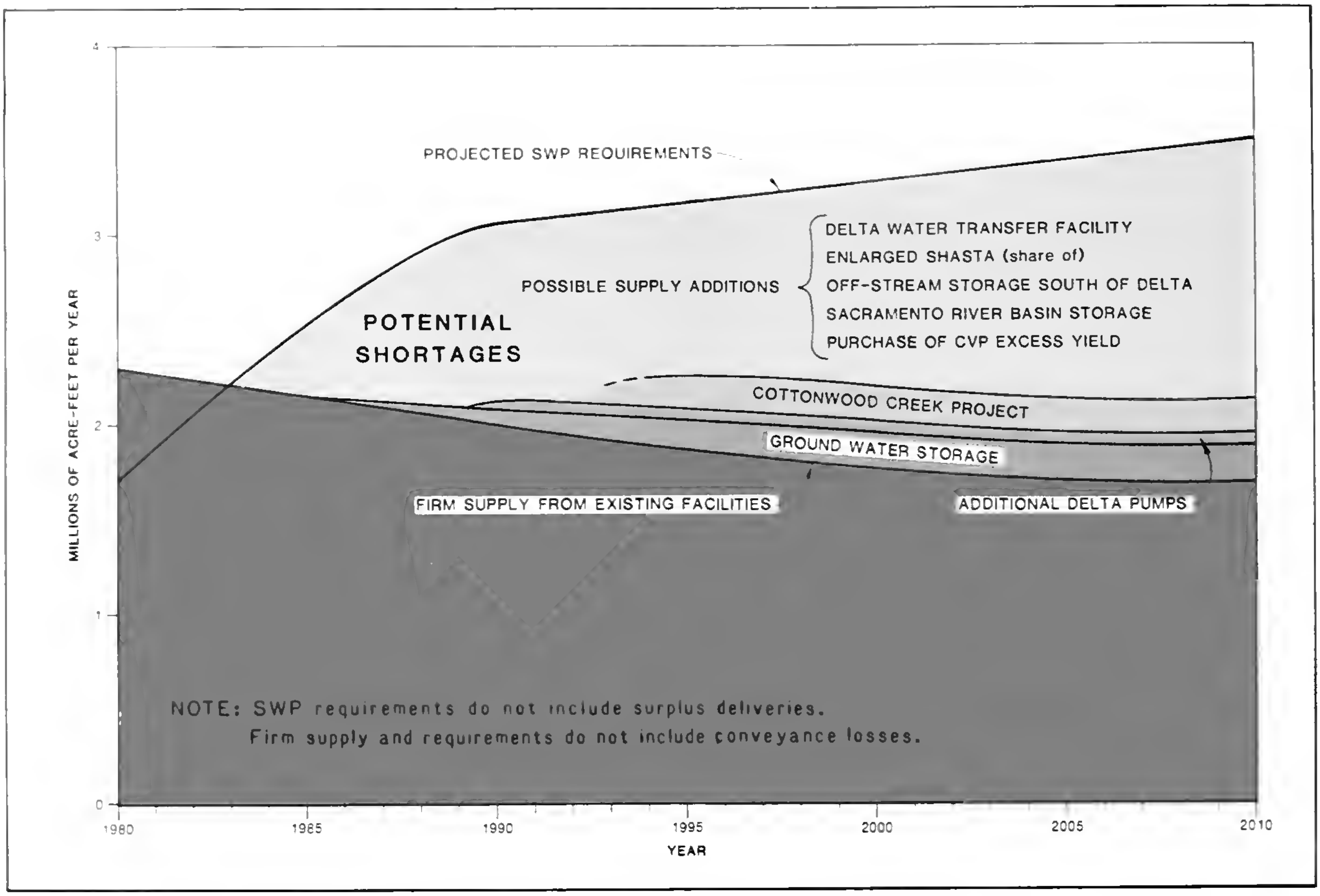
Dependable supply from existing and proposed facilities of the SWP under present and projected conditions is shown on Figure 48. About half the present SWP yield is derived from Lake Oroville, and the remainder is developed from surplus flows in the Delta and re-regulated in San Luis Reservoir. SWP project yield declines with time because Delta inflow is depleted by irrigation and urban development projected to occur in the areas of origin and because the CVP will be using Delta CVP supplies that are currently available to the SWP.[1]

For the next several years, SWP requirements can be met in average and wet years, but the risk of shortages will increase with the delay in adding facilities. Some additional yield (60,000 acre-feet) can be provided by installing the last four pumps in the Harvey O. Banks Delta Pumping Plant, bringing it up to its design capacity, and by proceeding with the ground water storage program to the extent possible without a Delta facility (200,000 acre-feet). Enlargement of the East Branch of the California Aqueduct will facilitate delivery of water to Southern California

Harvey O. Banks Delta Pumping Plant near Tracy, an SWP facility, lifts water from the Delta 244 feet into the California Aqueduct. The Delta Operations and Maintenance Center is situated at left, and Bethany Dam and Reservoir appear at top. Addition of the final four pumps to bring the plant to design capacity of 10,300 cubic feet per second will improve operational flexibility and provide additional supplies for the SWP.

[1] After studies for this report were completed, other more recent studies of coordinated SWP-CVP operation and revised operation of Oroville Reservoir show that the firm yield of the SWP is about 200,000 acre-feet greater for the period 1980-2010. This would reduce the potential shortages shown for the SWP later in this chapter.

Figure 48. SWP PROJECTED WATER REQUIREMENTS AND WATER SUPPLY SOURCES



ground water basins for storage underground; however, it does not add yield to the system. The Cottonwood Creek Project presently being planned by the Corps of Engineers (175,000-acre-foot yield) was assumed to proceed as planned.

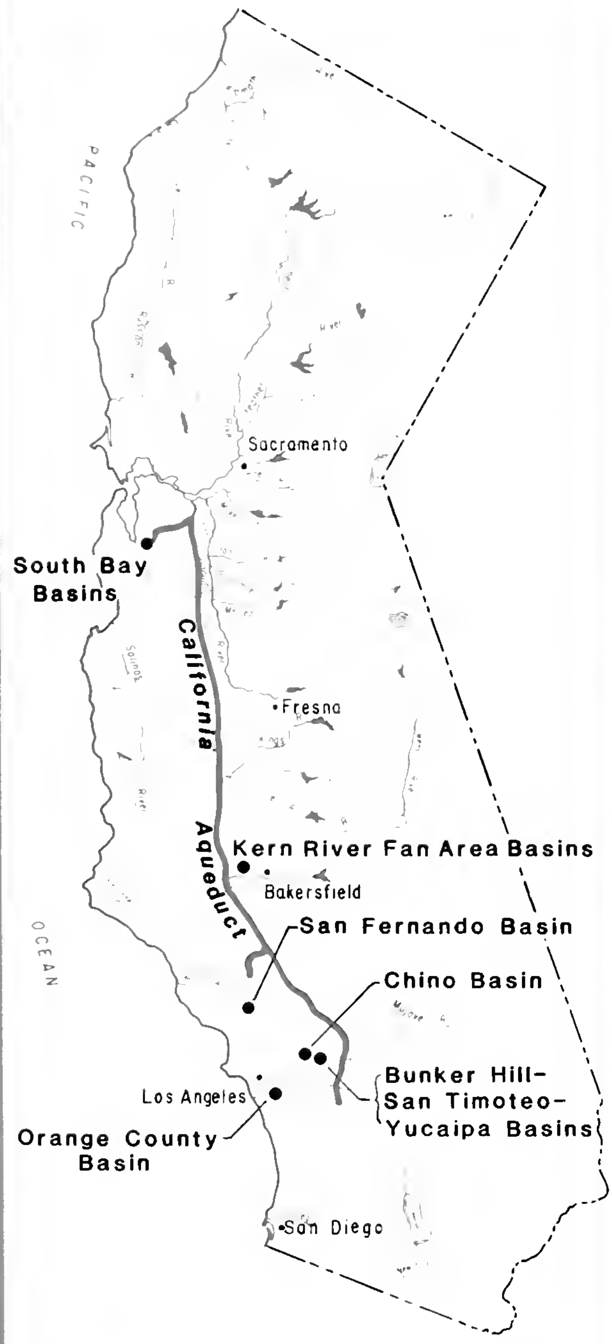
SWP Ground Water Storage Program. SWP yield can be increased significantly by a conjunctive operation program that involves storage of surplus water supplies in ground water basins in SWP service areas in the San Francisco Bay, Tulare Lake, Los Angeles, and Santa Ana HSAs. Surplus water would be stored during wet years and pumped for use during dry periods as part of the SWP yield.

Conjunctive operation of surface and ground water supplies has been practiced for many years in areas such as the Salinas Valley, Santa Clara County, the San Joaquin Valley, and in several parts of Southern California. This has been accomplished largely with local surface supplies. The SWP provides the opportunity for a substantial increase in conjunctive use through long-distance transfer of excess northern water. Six areas identified on Figure 49 appear to be the most promising for further evaluation. The basins ultimately selected, operated in conjunction with excess flows delivered through the California Aqueduct and its branches, could develop an estimated 200,000 acre-feet per year of dependable supply.

Conjunctive operation of the SWP and ground water basins will require:

- Basins having suitable location, empty storage capacity, adequate infiltration and transmissibility characteristics for recharge, and good water quality.
- Excess water at the Delta for conveyance to basins for recharge after all entitlements and water quality standards have been met.
- Capacity in the California Aqueduct between the Delta and the selected ground water basin at the same time the excess water is available at the Delta.

Figure 49. POTENTIAL GROUND WATER FEASIBILITY STUDY AREAS FOR STATE WATER PROJECT



Two methods of operation to augment water yield are possible—direct and indirect. Both methods depend on the availability of excess water in the Delta and capacity in the California Aqueduct.

The direct method would involve the use of SWP water for direct recharge of ground water basins. The recharged water would be extracted and delivered to SWP contractors during dry years. Surface facilities for this type of operation consist of spreading areas, conveyance facilities, and pumping facilities for future water extraction.

The indirect method would provide additional SWP water in wet years, in lieu of pumping water from the underlying ground water basin. Thus, ground water storage would be allowed to increase through normal recharge of the basin. The stored ground water would be pumped and used during drought periods when surface water deliveries were inadequate to meet requirements. Use of the indirect method would eliminate the need to construct spreading facilities required for a large-scale, direct-method operation.

Many issues must be resolved before ground water storage programs to augment SWP supplies can proceed. These include the equitable sharing of basin storage space, allocation of costs and benefits, and appropriate management procedures. For example, current SWP contracts allow for the sale of "surplus water" at a price equal to the cost of delivering the water, which is well below that of contract entitlement water. Under a ground water storage program, some of this more favorably priced water now being purchased by agricultural contractors would probably have to be diverted, instead, to ground water recharge.

SWP Brackish Water Reclamation Program. The Department of Water Resources is proceeding with implementation of a program to desalt brackish agricultural drainage water that could increase supplies for the SWP. The principal elements of the program are:

- To operate a demonstration desalting facility to obtain information needed for design and cost estimating of large-capacity plants.
- To determine possible sites for desalting facilities.
- To evaluate desalting facilities, delivery of brackish agricultural drainage water to desalters, conveyance of desalted water to places of use, and disposal of brine.
- To determine a schedule of demand for desalted water and availability of proposed desalting facilities.
- To develop a coordinated plan of operation for desalting facilities.
- To determine the feasibility of using brine from the desalter for salt-gradient solar ponds that would provide the energy for operating the desalter.

Preliminary determinations of existing and projected locations and characteristics of agricultural drainage water are already available from previous studies. The Department has evaluated the technology of desalting agricultural drainage in the San Joaquin Valley with pilot plant studies and is constructing a demonstration desalting plant to obtain design and cost data. The demonstration plant capacity of the desalter is 344,000 gallons per day. The data obtained from the facility will be used to evaluate large-scale desalting facilities designed to produce nominally 25,000 acre-feet per year. Desalting systems use considerable energy, and on-site energy recovery and power generation from salt-gradient solar ponds would reduce net energy requirements.

Projected Use of SWP Supply. The dependable supply of existing facilities of the SWP is shown in Figure 48. The line showing projected requirements reflects the effect of projected conservation measures and actions. Projections of supply are based on the assumption that certain facilities would be constructed as scheduled. The impact of potential SWP water shortage on growth, as well as other means of coping with the deficiencies, have not been determined.

The water use and water supply summaries for the San Francisco Bay, Tulare Lake, Los Angeles, Santa Ana, and San Diego HSAs presented later in this chapter discuss allocation of existing dependable SWP supplies. These allocations include the additional yield developed by the Cottonwood Creek Project, installation of the remaining Delta pumps, and a ground water storage program yielding 200,000 acre-feet. The remaining requirements of the SWP are shown as a potential shortage in dependable water supplies. A large portion of this potential shortage in the Tulare Lake HSA would probably be translated into ground water overdraft. In wetter-than-normal years, some of the shortage can be met from surplus water. It is also possible that other sources of supply can be added before 2010 to increase the yield of the SWP. The most promising of these are a Delta water transfer facility and purchase of uncontracted-for water from the CVP. Until additional water supplies are provided, the threat of shortages that are more frequent and more severe than under the present dry-year deficiency contract provisions will exist.

Federal Central Valley Project Supply

The net water supply capability of the existing Central Valley Project is projected to ultimately (beyond 2010) be about 9.45 million acre-feet per year, assuming full use of water by present and potential water contractors. The northern portion of the system (the Sacramento, American, and Trinity Rivers) will contribute 7.7 million acre-feet of this amount for use in the Sacramento River, American River, and Delta service area. The other units—New Melones, Friant, Hidden and Buchanan, Sly Park, and Sugar Pine Reservoirs—account for the remaining 1.75 million acre-feet.

The estimate for the northern CVP system is based on coordinated operation with the SWP to maintain Delta water quality standards in accordance with the State Water Resource Control Board's Decision 1485. The current level of Trinity River fish releases is assumed to continue indefinitely. The estimate does not include supply from the proposed Auburn Reservoir.

CVP water supply is predicated upon a considerable amount of reuse; that is, return flow to the Sacramento River and the Delta from upstream CVP service areas is counted again as project supply available for rediversion or to meet Delta outflow requirements. Therefore, if upstream use does not increase as projected, the CVP water supply would be reduced.

Under the 1980 operating criteria and level of development, the net water supply from the northern portion of the CVP system is about 6.5 million acre-feet per year. Since this total is not needed in all years to meet present contractual obligations, and because some conveyance systems have not been completed, operational spills and a portion of the releases to maintain instream flows indirectly become part of the Delta water supply and are shared with the SWP. In the future, these reserve supplies will be used to satisfy service area obligations and there will be a reduction in the Delta supply shared by the SWP.

The dependable supply potential of New Melones Reservoir is 210,000 acre-feet per year. The dependable supply of the Friant Division is 800,000 acre-feet annually, plus an average of 657,000 acre-feet of nonfirm supplies. The nonfirm supplies are used conjunctively with ground water in the service areas of the Friant-Kern and Madera Canals and result in firm supplies to those users. Hidden and Buchanan Reservoirs near Madera, completed by the Corps of Engineers in 1979, have been added to the CVP, and each provides 24,000 acre-feet per year to project yield. Sugar Pine Reservoir will provide 2,800 acre-feet annually to meet supplemental needs in the service area of the Foresthill Divide Public Utility District.

The San Felipe Division, presently under construction, will deliver water from San Luis Reservoir to Santa Clara and San Benito Counties. Facilities may be extended later to provide service to Monterey and Santa Cruz Counties. Principal features of the project are shown on Plate 1 and Figures 21 and 60. The project will provide about 216,000 acre-feet annually by 2020—145,000 acre-feet to Santa Clara County, 40,000 acre-feet to San Benito County, and 20,000 acre-feet to Santa Cruz and Monterey Counties.

About 60 percent of the water delivered to Santa Clara County will be used for recharge of the ground water basin. Nearly all the water provided to San Benito County will be delivered as surface water to replace boron-contaminated ground water and to bring agricultural land into production. Construction of project facilities to supply Santa Cruz and Monterey Counties is being deferred for the present time. Because of limited capacity in the Delta-Mendota Canal, the Department has agreed to wheel water for San Felipe through the California Aqueduct, provided the U. S. Bureau of Reclamation (USBR) first meets its share of Decision 1485 requirements.

Possible future additions to the CVP include the proposed Mid-Valley Canal, completion of Auburn Dam and Reservoir, and enlargement of Shasta Dam and Reservoir. A Mid-Valley Canal that could deliver water to areas of serious ground water overdraft in the eastern San Joaquin Valley has been studied jointly by USBR and the Department. The proposed alignment is shown on Plate 1 and Figures 66 and 68. The project would supply annually 500,000 acre-feet of dependable supply and 150,000 acre-feet of nonfirm water from existing and planned CVP reservoirs in the Sacramento River Basin and from surplus winter and spring flows in the Delta. Full realization of the project yield would require a Delta water transfer facility. Water would be conveyed from the Delta through the California Aqueduct or an enlarged Delta-Mendota Canal.

There are several issues and problems in connection with the proposed project that would require resolution before the project could move forward. If the California Aqueduct were used, capacity available for conveying the water would need to be determined. Water management measures to control the use of water in the service area would have to be implemented to ensure that overdraft was reduced and no additional land was irrigated. Allocation of CVP water supply for the project would need to be made. The cost, excluding new storage project costs, would be between $600 and $700 million at January 1980 price levels, depending on the alternative means assumed to convey the water from the Delta. Cost of irrigation water would depend on the extent of financial integration with the CVP, the effect of recent revisions of reclamation law, and the amount of CVP dependable supply that can be made available.

Construction of Auburn Dam was suspended in

Auburn Dam site on the North Fork American River. Downstream view shows the present status of construction. A 200-foot-high upstream cofferdam is situated in the foreground, with the dam's keyway or "notch" in the canyon visible just above. Work on the dam has been suspended, pending redesign to meet higher seismic criteria and reauthorization by Congress.

1975 because of increased seismic requirements. The dam has since been redesigned. The Auburn-Folsom South Unit of the CVP is being re-evaluated by the USBR, and a bill, H.R. 2219, for reauthorization of the unit was submitted to Congress in 1983. As planned, Auburn Reservoir would have a gross storage capacity of 2,326,000 acre-feet. Initial power plant installed capacity would be 300 megawatts. An additional 450 megawatts could be added later. The reservoir would add about 318,000 acre-feet per year to the dependable water yield of the CVP. Other project purposes are recreation, fish and wildlife enhancement, and flood control needed to control the standard project flood in the lower American River.

The estimated first cost of the Auburn-Folsom South Unit is $2.06 billion in 1982 prices. Of this amount, about $310 million had been expended through September 1981 on Sugar Pine Dam and Pipeline, Folsom South Canal, and Auburn Dam and Powerplant.

Enlargement of Shasta Reservoir also is the subject of joint study by USBR and the Department. Shasta Lake is the principal water storage facility for the CVP and has a storage capacity of 4.55 million acre-feet, which is only 80 percent of the long-term average annual runoff at the dam site. Consequently, there is sufficient unregulated runoff to justify substantial storage enlargement.

Studies conducted in 1978 by USBR indicate that the optimum upper limit of storage capacity would be 14 million acre-feet. Preliminary estimates indicate that about 1.4 million acre-feet of dependable dry-period yield could be developed from a reservoir of this size. The enlarged reservoir, together with an enlarged power plant, would increase present average annual generation of 2 billion kilowatthours by some 30 percent, depending on the mode of operation. The estimated first cost is $1.8 billion at 1981 prices.

Projected Use of CVP Supply. As stated earlier in this section, the long-range net supply (yield) of the CVP presently available for allocation to water users is about 9.45 million-acre feet per year. The entire Friant Division supply is presently committed. In the Auburn-Folsom South Unit, Sugar Pine Reservoir has just been completed, and its 2,800-acre-foot

Shasta Dam and Reservoir of the Central Valley Project, showing the outline of the proposed enlargement. Raising the present height of the dam by another 200 feet would create a 14-million-acre-foot reservoir and increase the dependable water supply by about 1.4 million acre-feet per year.

The Sacramento-San Joaquin Delta. Water right permits for the SWP and CVP require water quality in Delta channels to be maintained at prescribed levels as a condition for export of water from the Delta.

supply was assumed to be fully used by 2000. The dependable supply from New Melones Reservoir, 210,000 acre-feet, was assumed to be reserved for the designated service area within San Joaquin, Stanislaus, Tuolumne, and Calaveras Counties.

No additional conservation storage was assumed to be added to the CVP between now and 2010. The Folsom South Canal and the San Felipe Division were assumed completed, and the present Cross Valley Canal conveyance arrangement was assumed to continue.

Future water needs to be met from the CVP were projected to be 8.1 million acre-feet per year by 2010. This is an increase of one million acre-feet over the 1980 level. The major increases are projected to occur in the Tehama-Colusa Canal, American River, Folsom South Canal, and San Felipe service areas. There are potential demands in the proposed West Sacramento Canal and Mid-Valley Canal service areas, but those facilities are not now authorized and were not included in the foregoing estimates.

Impact of Delta Outflow Requirements on Operations of SWP and CVP

Both the SWP and the CVP develop part of their yield from surplus flows to the Delta. The Delta is the focal point of operations for the SWP and, to a considerable extent, for the CVP. The amount of Delta surplus flows available for export depends on amounts of inflow, Delta area consumptive uses, and Delta outflow requirements. These surpluses occur during winter and spring. During summer and fall, however, water must be released from both SWP and CVP reservoirs to comply with Delta outflow requirements.

Outflow requirements are established by the State Water Resources Control Board (SWRCB) as a condition of water rights issued for the CVP and the SWP. For the Delta, the SWRCB has reserved jurisdiction over terms and conditions affecting Delta water supplies in three general areas: (1) salinity control, (2) protection of fish and wildlife, and (3) coordination of terms and conditions of the respective permits for the CVP and SWP. In its water rights Decision 1485, which sets forth the terms and conditions currently in effect, the SWRCB recognized the uncertainty associated with future project facilities and the need for additional information on the effects of project operations and water quality conditions in the Delta and Suisun Marsh.

Figures 50 and 51 show uses of Delta inflow at the 1980 and 2000 levels of development. For both levels, in about 8 out of 10 years, annual Delta inflows are more than adequate to meet uses. In the other years, exports by the CVP and SWP would have to be reduced, as would required outflow under Decision 1485.

Figure 52 shows the monthly disposition of Delta inflow for a near-average water year (1928) and a very dry water year (1929) under the 1980 level of development. As typified by these two years, Delta exports for the CVP and the SWP are a combination of water released from storage and use of surplus flows. The cross-hatched area shows the extent to which release of stored water is required not only to meet export needs but also to meet local consumptive uses and water quality criteria in the Delta channels.

The Legislature has determined that an adequate water supply for all beneficial uses in the Delta must be maintained. Based on legislative declaration and statutory powers, the SWRCB has concluded that an adequate supply may require releases of a reasonable quantity of water from storage. Over the years, upstream water use has increased until net Delta outflow during July and August in all but above-normal runoff years would be inadequate, if it were not for CVP and SWP operational releases.

Figure 50. ANNUAL DELTA INFLOW AND ITS USES

1980

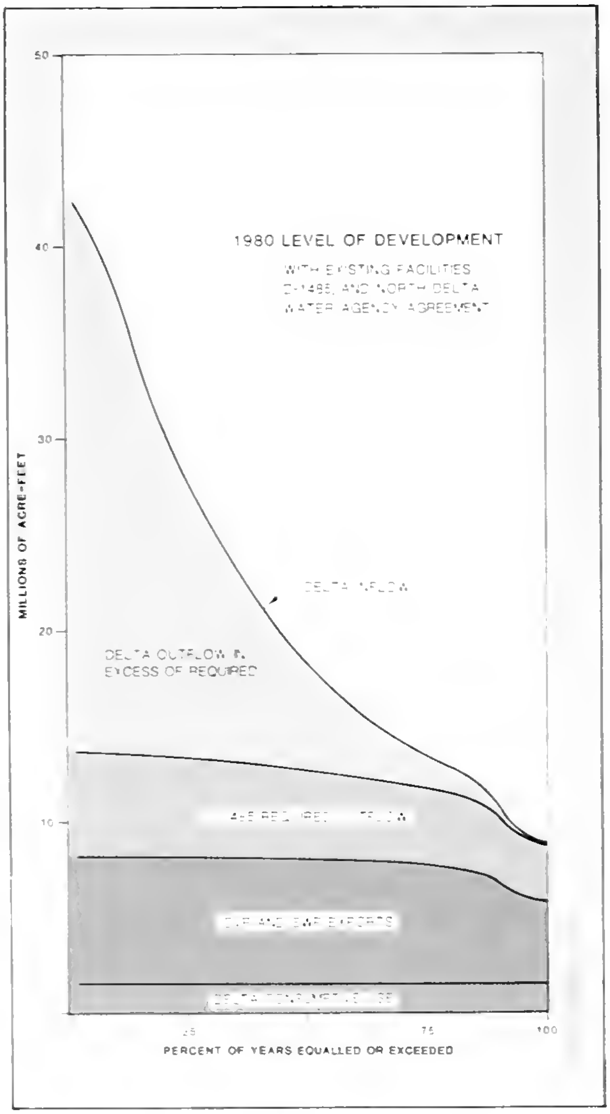


Figure 51. ANNUAL DELTA INFLOW AND ITS USES

2000

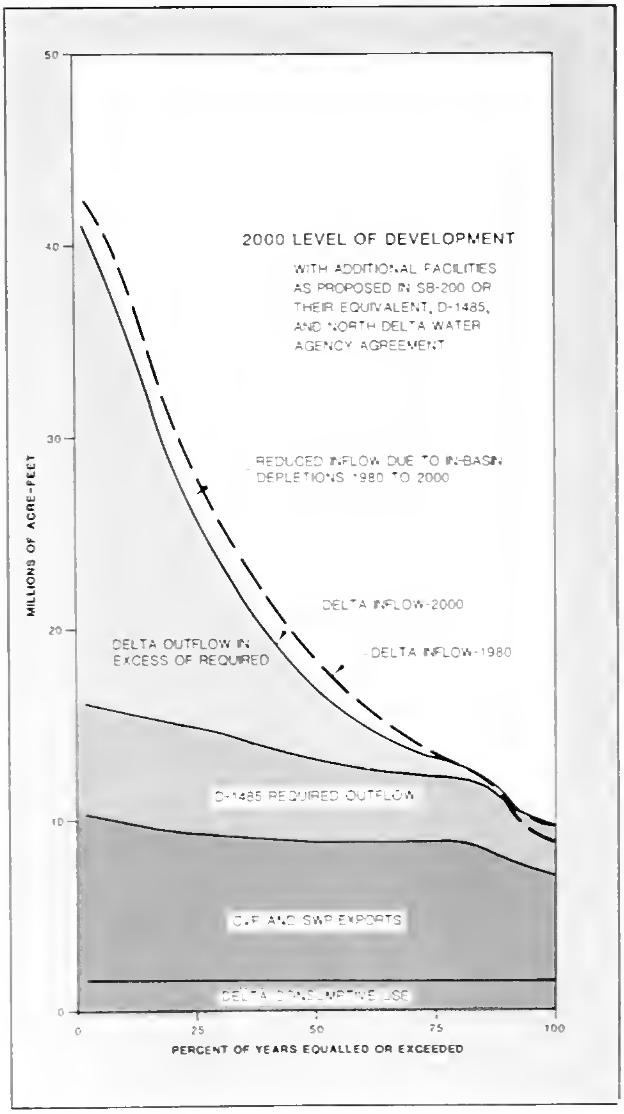
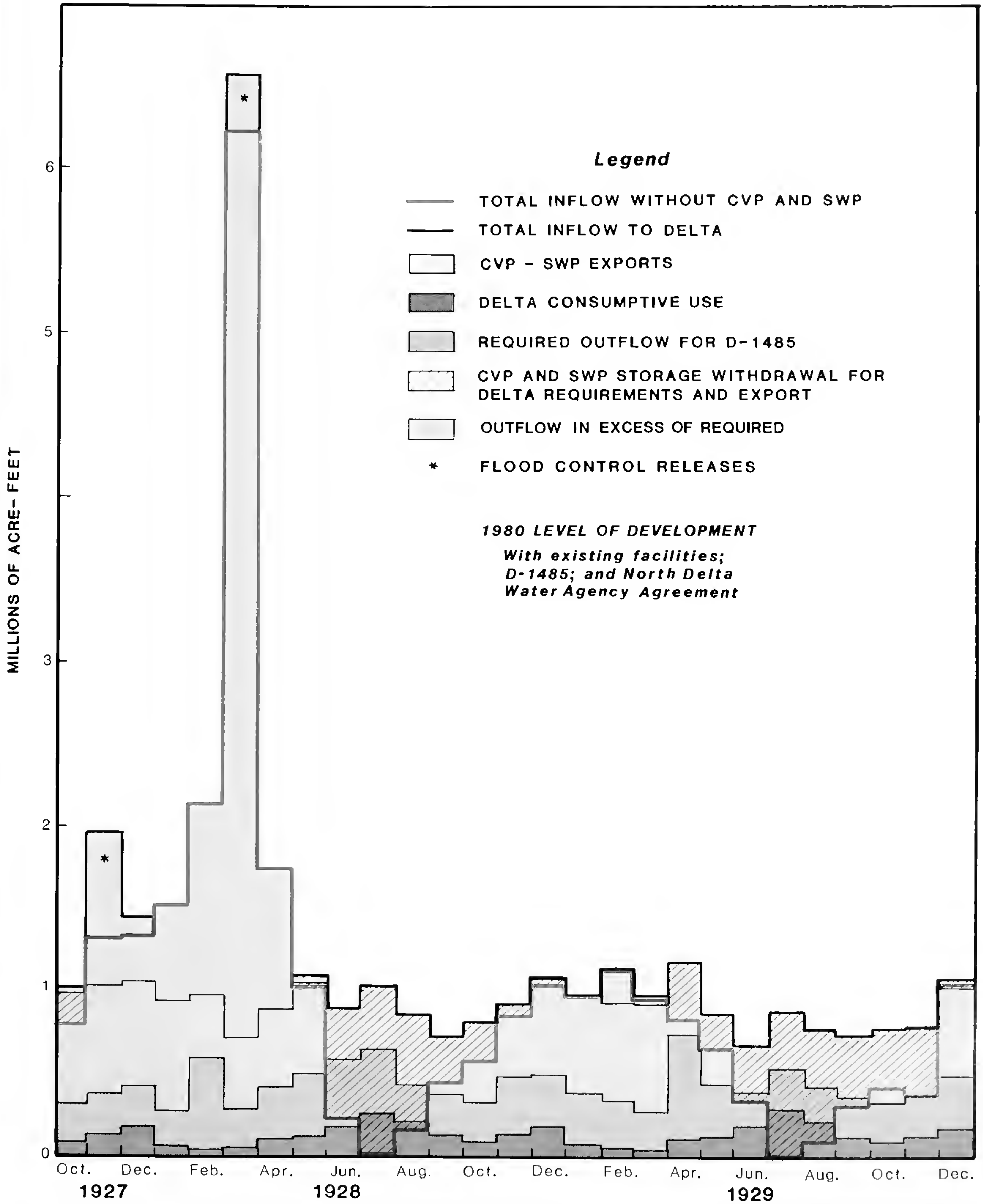


Figure 52. MONTHLY DELTA INFLOW AND ITS USES
FOR AN AVERAGE AND A DRY YEAR
1928 AND 1929



Water rights decisions for the CVP and the SWP recognize that the two projects should be compensated for the allocated cost of providing enhancement flows, but the SWRCB has no authority to specify the source of funds. Future legislation will have to provide for reimbursement of these allocated costs.

Figure 51 shows the effect of projected future developments in the Central Valley on Delta inflow and outflow. While the total volume of outflow is reduced somewhat from 1980 levels, peak flows, such as those shown for March 1928 in Figure 52, will not be significantly diminished.

Other Federal Water Projects

Other federal water projects include those constructed or proposed by the Corp of Engineers or USBR that are not part of the CVP. Information on completed projects that contribute to meeting water requirements within the State are shown in Table 55. Authorized projects and their present status are described here.

The Corps of Engineers' Cottonwood Creek Project (Tehama and Dutch Gulch Reservoirs) is the only new federal water supply project assumed to be available by 2010. As presently proposed, the SWP would acquire the project yield under provisions of the federal Water Supply Act of 1958. However, because of increased nonfederal cost-sharing recently proposed by the Corps, the Department is considering State construction of the project as an alternative.

The Butler Valley Dam and Blue Lake project on the Mad River was authorized by Congress in 1968 (see Plate 1). The project was proposed to provide a supplemental water supply for the mid-coastal Humboldt County region, flood protection for downstream areas, and reservoir-associated recreation. The project has been inactive since 1974.

The proposed Marysville Reservoir on the Yuba River has been under study by the Corps of Engineers since congressional authorization in 1966. In 1977, the Corps identified the Parks Bar site as the most desirable location for construction of a reservoir providing flood control, hydroelectric energy, water supply, recreation, and fish and wildlife benefits. The Corps discontinued study in 1980 after the USBR determined that it was not feasible to integrate the water supply into the CVP. Local interests in Sutter and Yuba Counties, seeking additional flood protection, proposed an agreement between the Yuba County Water Agency and the North Kern Water Storage District for a project that could provide local benefits, as well as export water supplies to alleviate ground water overdraft in portions of the Tulare Lake HSA. Yuba County voters rejected the proposal in November 1981, and the Marysville Reservoir project is now inactive.

Colorado River Water Allocation to California

Priorities for the use of Colorado River water in California are based on the 1931 Seven-Party Agreement, as modified in 1964 by the U.S. Supreme

TABLE 55

FEDERAL WATER SUPPLY PROJECTS IN CALIFORNIA OTHER THAN THE CENTRAL VALLEY PROJECT

Reservoir	*Capacity (acre-feet)*	*Stream*	*Hydrologic Study Area*	*Yield (acre-feet per year)*
Clear Lake [1]	527,000	Lost River	NC	——[2]
Lake Mendocino	122,000	Russian River	NC	54,000
Lake Sonoma [3]	281,000	Dry Creek	NC	115,000
Salinas	26,000	Salinas River	CC	5,000
Twitchell	240,000	Santa Maria River	CC	21,200
Cachuma	205,000	Santa Ynez River	CC	27,800
Casitas	252,000	Coyote Creek	SC	20,400
East Park	51,000	Stony Creek	SB	
Stony Gorge	50,000	Stony Creek	SB	108,000
Black Butte	160,000	Stony Creek	SB	
Lake Berryessa	1,602,000	Putah Creek	SB	209,000
New Hogan	325,000	Calaveras River	SJ	55,000
Pine Flat	1,000,000	Kings River	TL	165,000
Terminus	150,000	Kaweah River	TL	21,000
Success	85,000	Tule River	TL	7,000
Isabella	570,000	Kern River	TL	50,000
Stampede	225,000	Little Truckee River	NL	6,000 [4]

[1] In Modoc County
[2] Not estimated
[3] Completion 1984
[4] State of California share

Court's decree in *Arizona* v. *California*. Under the Seven-Party Agreement, a total of 5,362,000 acre-feet per year of Colorado River water was allocated to California (Figure 53). Additional present perfected rights of 55,000 and 3,000 acre-feet per year, respectively, were allocated for Indian reservation lands and miscellaneous entities.

In 1964, the U.S. Supreme Court, in *Arizona* v. *California*, apportioned to California 4.4 million acre-feet per year of the first 7.5 million acre-feet available for use by the three Lower Basin States (California, Nevada, and Arizona). The court also ruled that, if more than 7.5 million acre-feet were available, California would be entitled to 50 percent of the surplus. If insufficient water is available to provide the first 7.5 million acre-feet per year, then present perfected rights are first satisfied in order of their priority dates. After that, the Secretary of the Interior apportions the remaining available water, with the stipulation that no more than 4.4 million acre-feet per year, including present perfected rights, is apportioned to California.

In 1980, California used about 4.8 million acre-feet of Colorado River water. Of this amount, about 4.0 million acre-feet was used for irrigation, and The Metropolitan Water District of Southern California (MWD) used about 850,000 acre-feet.

When the Central Arizona Project begins delivering water (scheduled for 1985), California can no longer depend upon receiving more than 4.4 million acre-feet per year. As the junior appropriator, MWD will be limited to 550,000 acre-feet per year of fourth priority water under the Seven-Party Agreement, less the water taken by the three Indian reservations and miscellaneous present perfected right holders. This would reduce the total for MWD to about 492,000 acre-feet. After deducting 50,000 acre-feet per year for delivery system operating losses (seepage and evaporation), MWD will have a usable supply of about 442,000 acre-feet per year.

In addition, the annual supply of water available to agencies using Colorado River water could be further reduced by as much as 82,000 acre-feet, if the 1982 report by the special master, which recommended awarding further rights for water to Indian tribes in California along the Colorado River, is upheld by the U.S. Supreme Court. If MWD were to bear all those losses, the agency's cumulative losses by 2000 could be 190,000 acre-feet. The water delivered to Southern California by MWD would thus be reduced to 360,000 acre-feet per year.

Local Water Supply Projects

Total statewide dependable water supplies from projects developed by local water agencies, together with direct diversion of streamflow for local use, on an average, amounts to 11.1 million acre-feet per year. Major local water supply projects are shown on Plate 1 and Figure 21. Possible future local agency developments for water supply and other purposes are shown on Plate 1 and on figures presented in the HSA summaries later in this chapter. Several larger proposed hydroelectric power projects are also shown on Plate 1. Because the schedules for these projects are uncertain, the water supplies that would be developed were not included in future dependable water supplies. Their availability would reduce shortages indicated or would contribute to additional net water use.

While the supplemental water needs in many areas of the State must rely on service from the CVP and SWP, several local agencies have reserve supplies available that are adequate to meet all or part of their supplemental needs to 2010. However, in some instances, such as Yuba County, use of the supply will require construction of conveyance or distribution facilities.

The water supplies available and the assumptions made regarding their future use are presented in the HSA summaries later in this chapter.

Ground Water Availability and Use

Statewide, total ground water in storage is estimated to be 857 million acre-feet; even in basins partially depleted by long-term overdrafting, substantial quantities of ground water remain. With the basic assumption that there would be essentially no controls on ground water pumping before 2010, projected increases in use would be governed largely by pump-

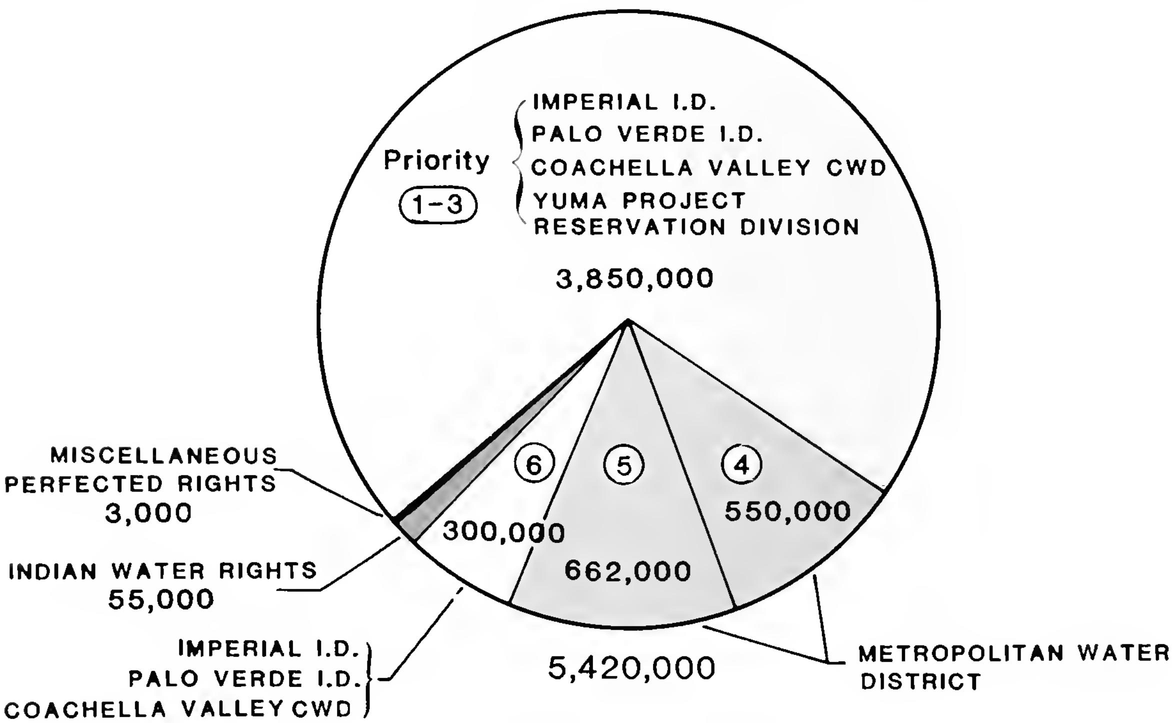
Havasu Pumping Plant at Lake Havasu on the Colorado River, a facility of the Central Arizona Project. Full use is expected by 1990, at which time California can no longer depend on receiving more than 4.4 million acre-feet per year.

Figure 53. ALLOCATION OF CALIFORNIA'S COLORADO RIVER WATER SUPPLY

(IN ACRE-FEET)

PRESENT

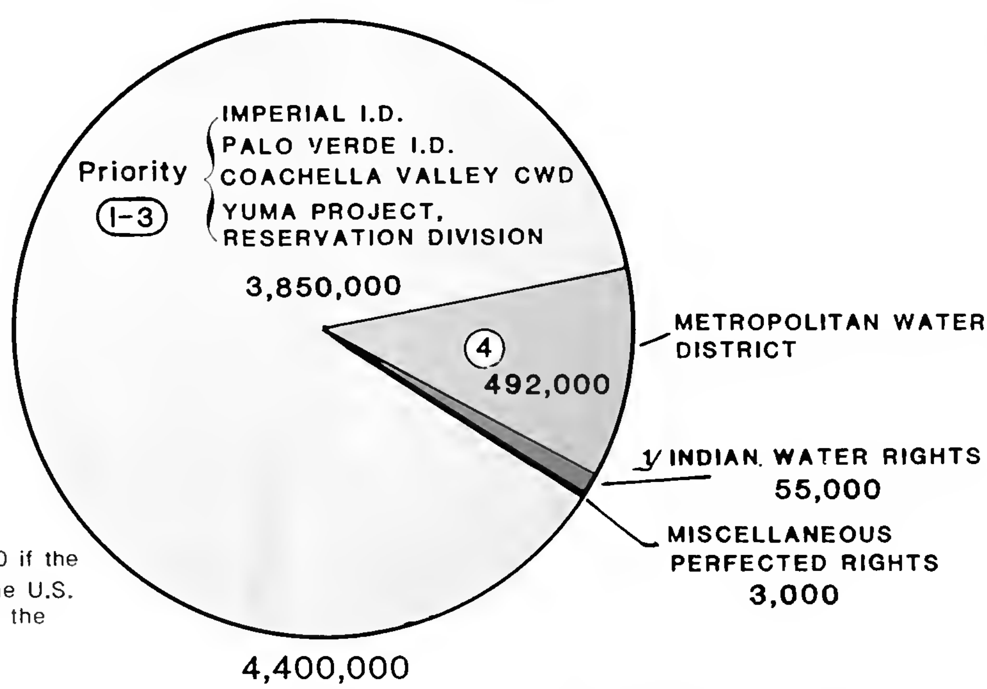
Before Central Arizona Project begins operations



(PRIORITIES FOR USE OF 5,362,000 ACRE-FEET ARE AS SPECIFIED UNDER SEVEN-PARTY AGREEMENT)

FUTURE

After Central Arizona Project reaches full operation about 1990



1/ Could be increased by 82,000 if the 1982 recommendation by the U.S. Special Master is upheld by the Supreme Court

(APPORTIONMENT WHEN CALIFORNIA IS LIMITED TO 4,400,000 ACRE-FEET PER YEAR)

ing costs. Information on the availability of and depth to ground water is presented in Chapter III.

In most areas of the Central Valley, ground water of good quality is available within economic pumping limits for projected needs. Results of economic modeling studies of Central Valley agricultural development indicated that increasing costs for ground water pumping, due to greater pumping lifts and higher energy costs, would not significantly slow the growth of irrigated agriculture during the next 30 years.

Outside the Central Valley, new or greatly expanded ground water extractions are occurring in several areas of the State, especially Northern California. The information available is insufficient to determine the potential for long-term sustained pumping from most of these basins. In deriving projections of future net water use, it was assumed that availability and cost of water in these areas would not be limiting factors, except in the South Lahontan HSA, where high water costs resulted in reduced irrigated area.

Ground Water Use

In 1980, ground water provided 39 percent of the applied water in California. Between 1980 and 2010, the statewide average annual overdraft is projected to increase from 1.8 million acre-feet to 2.9 million acre-feet, largely as the result of additional irrigated agriculture in the San Joaquin and Tulare Lake HSAs. Ground water overdraft estimates for the San Joaquin and Tulare Lake HSAs show an increase of about 300,000 acre-feet and 900,000 acre-feet, respectively, by 2010. In the SWP service area of the Tulare Lake HSA, the overdraft situation will worsen if the SWP cannot meet its contractual commitments. This could increase ground water overdraft at 2010 by as much as 600,000 acre-feet per year. Surplus SWP water and CVP nonfirm supplies have been used in recent years in place of ground water pumping and for direct recharge of ground water basins.

Dependable ground water supplies and present and projected overdraft are discussed in the HSA summaries at the end of this chapter. The discussion also includes local ground water conditions and potential quantity and quality problems.

Reclaimed Waste Water

At the 1980 level of development, reclaimed waste water provided 0.5 percent of the applied water in California. This represents only a small part of the total waste water produced. Constraints on the use of reclaimed waste water because of health, physical, and economic reasons are discussed in Chapter III. A higher level of use is expected in the future, based on the following assumptions:

- Reuse of water supplies will become more intensive because of economic conditions and the conservation ethic.
- Ground water recharge will become the most significant form of future reuse, and guidelines for increasing such use will be adopted by health agencies.

Legal Requirements and Public Acceptance

Regulations and requirements regarding the quality of water from all sources subject to public use are set by federal, State, and local authorities. State regulations and requirements are prescribed in the Water Reclamation Law (Division 7, Chapter 7 of the State Water Code). Statewide waste water reclamation criteria are set by the Department of Health Services (DHS) for those uses of reclaimed waste water that affect the public health. Theregional water quality control boards set requirements regarding the waste water reclamation criteria on either the producer or the user, or both.

Results from on-going studies on the effects of reclaimed waste water will probably lead to relaxation of the criteria for controlling use, thereby allowing additional municipal and industrial reuse.

Criteria to protect public health have been established for recreation impoundments and landscape irrigation. While DHS has not yet established waste water criteria for ground water recharge, it has issued a position paper pertaining to the development of basin plans for the SWRCB. The current rule prohibits direct injection to ground water and requires consideration of surface spreading on a case-by-case basis. DHS further recommends against waste water reuse in small ground water basins because the quantity to be reused would be large in relation to the total quantity of water in the basin.

The public is conscious of the need for conserving water resources, and many persons feel that use of reclaimed waste water is acceptable, provided that precautions are taken to protect public health. However, the public does not generally support the use of reclaimed waste water for direct domestic uses.

Role of the Department of Water Resources

The Department of Water Resources has for many years had statutory responsibility to study and promote waste water reclamation. This responsibility was reiterated and updated by the 1973–74 Legislature in Assembly Bill 3815, referred to as the Waste Water Reuse Law of 1974. In addition to re-expressing State policy that "There should be maximum reuse of waste water," the bill directs the Department to study the technology for reusing waste wa-

ter and further the reasonable application of such use.

The Department's waste water reclamation activities include:

- Support of research in waste water reclamation technology.
- Participation in regional waste water reclamation planning and development.
- Determination of the feasibility of local waste water reclamation projects for inclusion in the SWP.

The Department supports research and demonstration programs to provide information for assessing health concerns and environmental impacts, determining statewide marketability of reclaimed water, and developing low-energy waste water reclamation projects. It has also participated in a number of regional studies on the use of reclaimed waste water.

Development of regional waste water reclamation plans has been completed for the San Francisco Bay area and Los Angeles-Orange Counties. The planning study in San Diego County is nearing completion.

Possibilities for using treated municipal waste water for irrigated agricultural use in the Castroville area are being evaluated by the Monterey Regional Water Pollution Control Agency. It is conducting a seven-year study, of which five years are being spent in field studies that will be completed in 1986. Program costs are estimated to be $7.5 million. The Department of Water Resources is providing technical assistance and is contributing $80,000 annually.

Projected Use of Reclaimed Waste Water

Present discharge requirements for sewage treatment plants result in the production of effluent that either meets or approaches health criteria for landscape irrigation such as parks and golf courses, certain industrial uses, and ground water recharge. More highly treated waste water is being produced than is being put to beneficial use. Projected waste water reclamation for the major urban areas is shown in Table 56. Table 57 summarizes the projected use of reclaimed waste water for each HSA. Use of reclaimed waste water for beneficial purposes will reduce the need for additional fresh water supplies. Almost half the increase in the use of reclaimed waste water is projected to occur in the Los Angeles HSA, and, by 2010, almost 60 percent of total waste water use will take place in the South Coastal region.

Comparison of Water Supply and Projected Use

For the purposes of analysis, dependable supplies were balanced against projected use for a normal year. This means that, for a normal year, supply and net use would be in balance, with no shortages. For wetter years, there would be surplus surface water supplies; for dry years, deficiencies as a percentage of normal-year requirements would be imposed by the CVP and SWP, in accordance with their contracts. Other users relying on surface supplies would face varying degrees of shortage in dry years. Ground water supplies are based on long-term averages. Pumping in dry years will cause the water table to drop, but the level recovers in wet years.

TABLE 56

PROJECTED INCREMENTAL INCREASE IN USE OF RECLAIMED WASTE WATER BY MAJOR URBAN AREAS[1] BY DECADES TO 2010

(In acre-feet)

Region	*HSA*	*1990*	*2000*	*2010*	*Increase 1980–2010*
San Luis Obispo County[2]	CC	4,500	2,000	0	6,500
Santa Barbara County[3]	CC	10,000	0	0	10,000
Ventura County[4]	LA	15,700	3,900	0	19,600
Orange-Los Angeles Counties[5]	LA, SA, SD	48,200	118,100	76,400	242,700
San Bernardino-Riverside Counties[6]	SA	11,000	0	0	11,000
San Diego County[7]	SD	20,000	10,000	0	30,000
TOTAL		109,400	134,000	76,400	319,800

[1] Assumes some relaxation of Department of Health Services restrictions on recharge of ground water basins.

[2] Jenks and Adamson, Consulting Sanitary and Civil Engineers. *South San Luis Obispo County Sanitation District—Wastewater Treatment Plant Improvements and Effluent Disposal Project*, Project Report, March 1976.

Jenks and Harrison, Consulting Sanitary and Civil Engineers. *Wastewater Treatment, Disposal and Reclamation Facilities for the City of San Luis Obispo*, January 1977.

John Carollo Engineers. *Morro Bay—Cayucos Wastewater Treatment and Disposal Facilities*, Project Report, September 1978.

[3] City of Santa Barbara. *Santa Barbara Reclamation Project Phase I Landscape Irrigation*, Conceptual Report, January 1980.

PRC Toups. *Goleta County Water District 201 Facilities Plan for Wastewater Reclamation*, Project Report, May 1980.

[4] CH_2M Hill and County of Ventura. *Ventura Countywide Wastewater Reuse Study, Facilities Plan*, December 1981.

Department of Water Resources. *Ventura Countywide Water Reuse Study*, Memorandum Report, June 1982.

[5] Orange and Los Angeles Counties' Water Reuse Study. *Summary Facilities Plan*, April 1982.

[6] Department of Water Resources, Southern District. *Task No. 5, Evaluate Potential Wastewater Reclamation Projects in Southern California*, June 1979.

[7] San Diego City/County Water Reuse Study Group. *San Diego City/County Water Reuse Study—Work Plan*, June 1978.

Department of Water Resources, Southern District. *Status Report on San Diego City/County Water Reuse Study*, Memorandum Report, June 1982.

TABLE 57
PRESENT AND PROJECTED USE OF RECLAIMED WASTE WATER BY HYDROLOGIC STUDY AREA BY DECADES TO 2010
(In 1,000s of acre-feet)

HSA	*1980*	*1990*	*2000*	*2010*	*Increase 1980–2010*
NC	9	10	10	10	1
SF	10	11	13	15	5
CC	9	25	27	27	18
LA	59	101	196	267	208
SA	29	47	73	78	49
SD	9	43	55	55	46
SB	17	22	23	25	8
SJ[1]	21	25	29	33	12
TL[1]	67	78	86	99	32
NL	5	6	7	8	3
SL	9	13	15	15	6
CR	3	20[2]	33[2]	45[2]	42
TOTAL	247	401	567	677	430

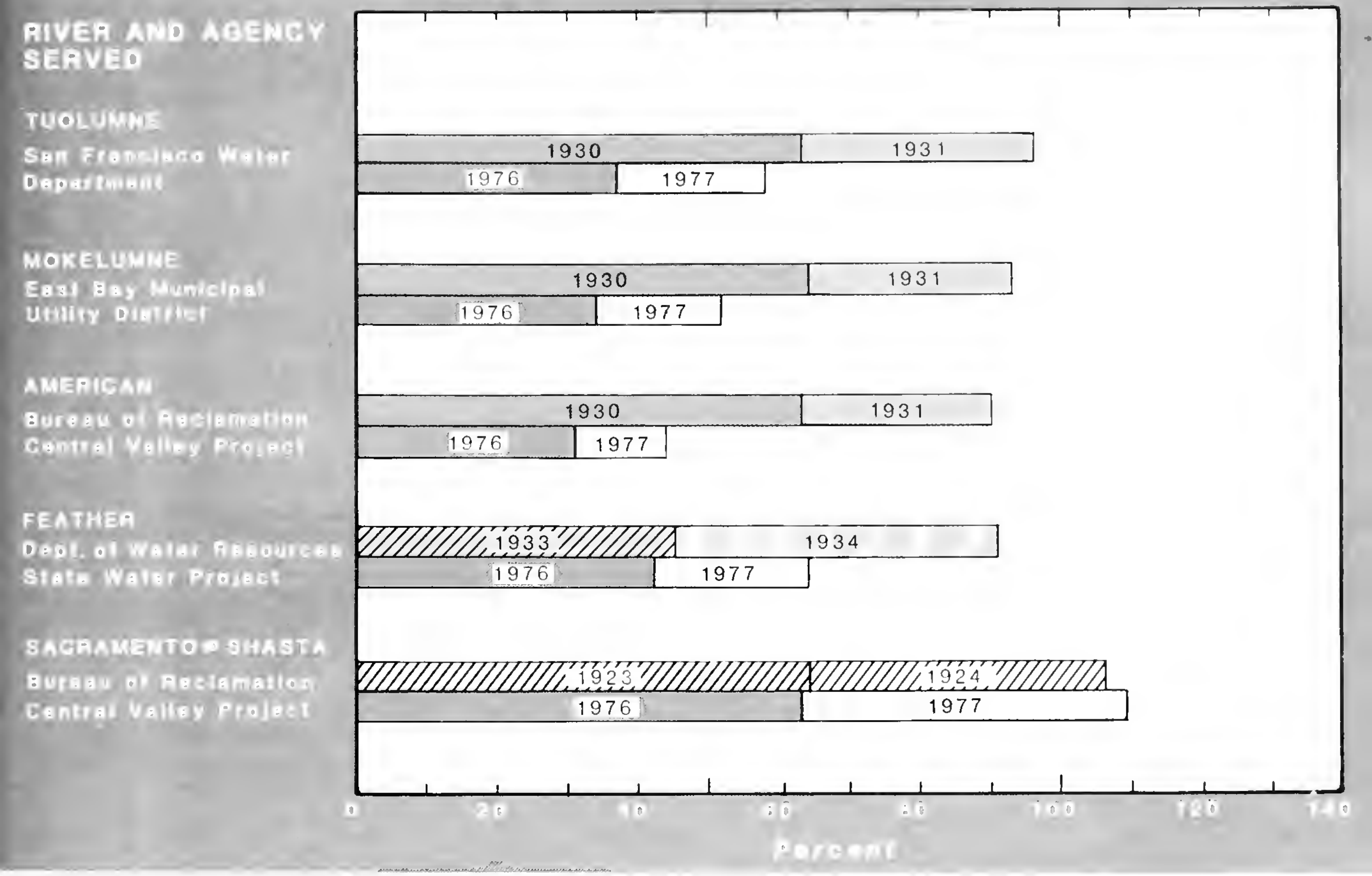
[1] Does not include planned reclamation of agricultural drainage water.
[2] Includes reclaimed agricultural return flows (normally lost to the Salton Sea) for power plant cooling

Dependable supply is defined as the maximum annual quantity of water that normally can be made available each year under an assumed reoccurrence of historic hydrologic conditions and a specified delivery schedule that may include specified deficiencies during critical dry periods. For large systems such as the SWP and the CVP, the critical period is all or part of the sequence of years from 1928 through 1934. For projects with less carryover storage, the critical period may be only two years or less. For smaller local water storage projects and direct diversion from rivers, average water supplies were assumed as the dependable supply. Where conjunctive use of surface and ground water supplies is practiced, as in many areas of the Tulare Lake HSA and the South Coastal region HSAs, the ground water storage regulates the average surface supply essentially into a dependable supply.

Water Factory 21 in Orange County. Operation of this plant, together with the primary and secondary treatment of municipal waste water at the plant appearing at top, involve most of the treatment processes in use today. Treated water produced by advanced treatment and desalted water are blended with water from deep wells and then injected underground to form a barrier to sea water intruding into the ground water in the region.

Figure 54. WATER YEAR NATURAL BASIN RUNOFF
October 1, 1976-September 30, 1977

Figure 55. CUMULATIVE UNIMPAIRED RUNOFF FOR TWO YEAR DROUGHTS FOR SELECTED CENTRAL VALLEY SUPPLY SOURCES (WATER YEARS IN PERCENT OF NORMAL)



Effects of 1976–1977 Drought Period on Estimates of Dependable Supply

The recent drought years, 1976 and 1977, were the two driest consecutive years in recorded history for most of the northern and central regions of California. Runoff from Sierra Nevada river basins was far less than the previous driest two-year periods, 1930–1931 or 1933–1934. Runoff from the northern Cascade Range was essentially equal to that of the previous driest period, 1923–1924. Figure 54 shows computed and estimated natural runoff of river basins in percent of normal for the 1977 water year.

Figure 55 compares these dry periods for streams that are the primary sources of supply for the San Francisco Bay area, the CVP, and the SWP. It shows that the principal water supply sources for the San Francisco Bay area were more severely affected by the 1976–1977 drought than by the previously worst two-year period, 1930–1931. The figure also reveals that the drought of 1976–1977 was less severe to the north, with the impact on inflow to Shasta Lake about half as severe as the impact on American River inflow to Folsom Lake.

For the Bay area supply sources, the new dependable supply is less than the estimate of dependable supply based on the 1928–1934 critical period. For the East Bay Municipal Utility District, dependable supply was reduced the greatest amount—30 percent. While this reduction appears severe, there is a compensating factor made apparent by the recent drought. A policy of imposing additional conservation measures in dry years could partially offset the effect of the new critical operating period on system dependable supply. Previously, in determining dependable surface water supply, the usual practice was to assume no supply deficiencies for urban uses, and variable deficiencies for agricultural uses. During the drought, urban areas showed that average water

use could be reduced by up to 25 percent from pre-drought levels without serious problems in most cases. This would indicate that planning for some urban shortages during severe droughts could be an acceptable management practice. However, similar reductions in use in the future cannot be as easily achieved because of the extent to which urban water conservation is now being practiced.

Dry-Year Realities. A comparison of dependable water supplies with average water use is acceptable for long-range planning where a high degree of accuracy in determining shortages is not essential. However, it should not be presumed that, during a severe drought, water needs can be met within the specified level of deficiencies assumed for project yield analysis. This shortcoming became apparent during the drought, especially for those projects with little or no dependable supplies in excess of current needs. Basically, two related things happened. First, water requirements increased over average-year requirements because soil moisture available to crops from winter rainfall was below normal. Second, streamflow in some cases was less than expected because of increased percolation to ground water from stream channels. For example, the Sacramento River, a major conveyor for the CVP and the SWP, lost water in its lower reaches to ground water recharge because of increased ground water pumping near the river. This caused the water table near the river to fall below the river level and water to percolate from the river into the adjacent ground water aquifer.

During a drought period, crop and lawn irrigation may begin earlier and, for perennial vegetation, continue later in the year. When project operation studies were conducted, water supply deficiencies for a dry year were based on water uses in an average year. However, actual shortages for a particular year may be much greater than the amount so computed.

Cosumnes River near Sloughhouse, as it appeared in November 1977. Lowered ground water tables during the drought caused more water to percolate from stream channels, reducing or, as here, entirely depleting streams that flowed across alluvial areas.

Statewide Summary of 1980 and Projected Net Water Use and Water Supplies

This section, along with the following section, which summarizes net water use and supply by Hydrologic Study Areas, brings together the present and projected net water use and the water supplies that will be needed by decades to 2010. The data summarized in Tables 58 and 59 show that an imbalance between use and supply in some major water-using areas will increase steadily to 2010. This imbalance, which includes shortages in the SWP, is expected to increase ground water overdraft substantially.

Dependable supplies for both the CVP and the SWP are less than the average supply available in about four out of five years. Although annual ground water overdraft is projected to increase about 1.1 million acre-feet between 1980 and 2010, it is expected that, in above-normal water years, excess surface water will be available for use in lieu of pumping ground water or for direct recharge, provided there is an adequate conveyance system. Consequently, the projected overdraft amounts may be overstated for some HSAs. An example of the use of excess surface water supplies to reduce ground water overdraft exists in the Tulare Lake HSA. The overdraft shown in 1980 is less than in earlier years because of the use of surplus surface SWP supplies. However, the SWP will likely be in a shortage situation, at least in the near future, and available supplies will be needed to meet projected requirements. Therefore, no reduction in overdraft was projected because surplus water will likely be available only in the very wettest years.

In some HSAs overdraft is projected to continue but, at the same time, substantial reserve surface supplies are indicated. Reserve supplies are developed but these supplies are not available to other parts of an HSA because distribution facilities or institutional arrangements are lacking.

Further details pertaining to net water use and related water supplies are presented for each HSA in the following section of the report.

TABLE 58
PROJECTED STATEWIDE USE OF WATER SUPPLIES BY DECADES TO 2010
(In 1,000s of acre-feet)

	1980	*1990*	*2000*	*2010*	*Change 1980–2010*
NET WATER USE					
Irrigation	27,045	27,865	28,215	28,725	1,680
Urban	4,978	5,670	6,205	6,840	1,862
Wildlife and Recreation	646	700	710	720	74
Energy Production	59	120	160	175	116
Conveyance Losses	1,093	930	865	870	−223
TOTAL	33,821	35,285	36,155	37,330	3,509
DEPENDABLE WATER SUPPLY					
Local Surface Water Development	9,274	9,350	9,350	9,390	116
Imports by Local Water Agencies	1,808	1,455	1,440	1,455	−353
Ground Water	5,839	6,010	5,980	5,990	151
Central Valley Project	7,077	7,690	7,950	8,110	1,033
Other Federal Water Development	5,115	5,110	5,180	5,200	85
Waste Water Reclamation	247	400	560	675	428
State Water Project	2,656 [1]	2,310	2,320	2,315	−341
TOTAL	32,016	32,325	32,780	33,135	1,119
GROUND WATER OVERDRAFT	1,790	1,950	2,245	2,875	1,085
SHORTAGE	15	1,010	1,130	1,320	1,305
RESERVE SUPPLY	1,413	820	860	955	−458

[1] Includes SWP surplus water deliveries.

TABLE 59
SUMMARY OF PRESENT AND PROJECTED NET WATER USE AND WATER SUPPLY BY HYDROLOGIC STUDY AREA BY DECADES TO 2010
(In 1,000s of acre-feet)

Year	NC	SF	CC	LA	SA	SD	SB	SJ	TL	NL	SL	CR	TOTAL
NET WATER USE													
1980	1,081	1,204	1,099	1,906	962	634	7,464	6,341	8,188	421	419	4,102	33,821
1990	1,180	1,275	1,175	1,995	1,050	715	7,935	6,580	8,425	450	415	4,090	35,285
2000	1,200	1,325	1,195	2,015	1,100	805	7,985	6,750	8,700	455	425	4,200	36,155
2010	1,230	1,395	1,200	2,095	1,180	890	8,185	7,020	9,030	470	410	4,225	37,330
DEPENDABLE WATER SUPPLY													
1980	1,080	1,197[1]	870	1,824	952	634	7,371	5,949	7,332[1]	416	316	4,075	32,016[1]
1990	1,180	1,225	985	1,870	1,050	625	7,835	6,130	6,580	440	355	4,050	32,310
2000	1,200	1,260	1,005	1,955	1,085	625	7,885	6,240	6,590	450	355	4,130	32,695
2010	1,230	1,330	1,015	2,030	1,095	630	8,015	6,280	6,600	460	310	4,140	33,050
GROUND WATER OVERDRAFT													
1980	0	7	224	82	10	0	85	391	856	5	103	27	1,790
1990	0	20	180	0	0	0	70	430	1,190	10	40	10	1,950
2000	0	0	180	0	0	0	60	470	1,450	5	50	30	2,245
2010	0	0	175	0	0	0	120	680	1,770	10	70	50	2,875
SHORTAGE													
1980	1	0	5	0	0	0	8	1	0	0	0	0	15
1990	0	30	10	125	0	90	30	20	655	0	20	30	1,025
2000	0	65	10	60	15	180	40	40	660	0	20	40	1,215
2010	0	65	10	65	85	260	50	60	660	0	30	35	1,405
RESERVE SUPPLY													
1980	9	138	17	164	203	46	535	191	56	17	33	4	1,413
1990	85	110	0	0	0	0	275	320	10	20	0	0	820
2000	75	190	0	0	0	0	340	220	0	20	15	0	860
2010	60	220	0	0	0	0	370	230	0	20	55	0	955

[1] Includes SWP surplus water deliveries

HYDROLOGIC STUDY AREA SUMMARIES OF NET WATER USE AND WATER SUPPLY

This section compares present and projected net water use with dependable water supply for each of the 12 Hydrologic Study Areas (HSAs). Deficiencies in supply appear in the tables as ground water overdraft or shortage. The section also highlights related water management issues within the HSAs. Net water use values in the tables include the effect of anticipated water conservation measures.

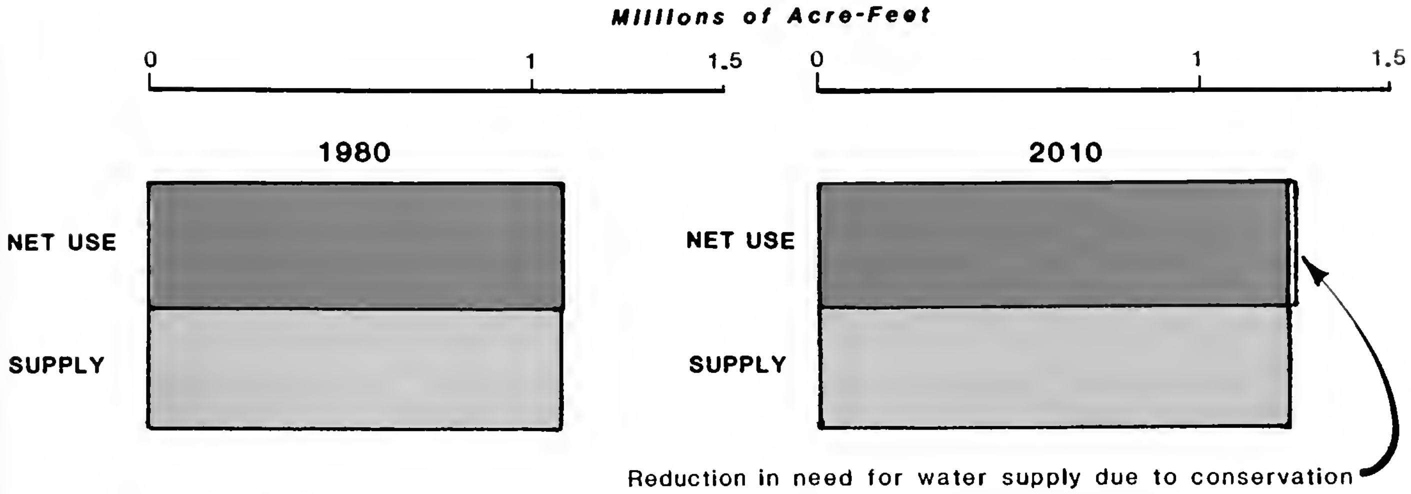
Following are explanations of terms that identify the types of water use and the sources of supply presented in the HSA summary tables.

- ***Irrigation, Urban, and Wildlife and Recreation Net Water Use.*** Derived as described in Chapter IV.
- ***Energy Production.*** Includes both power plant cooling and enhanced oil recovery as described in Chapter IV.
- ***Conveyance Losses.*** Water irrecoverably lost while supplies are being conveyed from the source to the area of use.
- ***Total Net Water Use.*** The sum of evapotranspiration of applied water (ETAW), irrecoverable distribution system losses, and outflow from each Planning Subarea (PSA).
- ***Local Surface Water Development.*** Includes local project supplies and direct diversion of surface water other than federal and State Water Project diversions.
- ***Imports by Local Water Agencies.*** Interbasin diversions (from one HSA into another) by a local agency.
- ***Ground Water.*** Annual average recharge from natural sources, plus recharge from local reservoirs operated to augment natural stream percolation, or to supply recharge basins. It does not include percolation of imported supplies.
- ***Central Valley Project.*** Existing facilities, plus the San Felipe Division.
- ***Other Federal Water Development.*** Corps of Engineers' projects and USBR projects other than the CVP.
- ***Waste Water Reclamation.*** Reclaimed waste water used to meet needs that would otherwise be met by fresh water.
- ***State Water Project.*** Existing facilities, plus specific additions shown in Figure 48.
- ***Ground Water Overdraft.*** Long-term excess of withdrawals over replenishment.
- ***Shortage.*** The difference between dependable supply and projected requirements.
- ***Reserve Supply.*** Dependable surface water supply that is available but not needed at a particular time and that cannot be distributed to other areas of need because of a lack of conveyance facilities and/or institutional arrangements.

The bar charts compare the sum of net water use (by type) with the related water supply (by source). The shaded extension of the net use bar represents the reduction in need for water supply resulting from projected urban and agricultural water conservation.

Figure 56. SURFACE WATER PROJECTS – NORTH COAST HYDROLOGIC STUDY AREA

Figure 57. WATER SUPPLY AND USE SUMMARY NORTH COAST HYDROLOGIC STUDY AREA 1980-2010



Thousands of acre-feet

NET WATER USE	1980	1990	2000	2010	CHANGE 1980-2010
IRRIGATION	714	780	790	810	100
URBAN	151	170	180	190	40
WILDLIFE AND RECREATION	216	230	230	230	10
ENERGY PRODUCTION	—	—	—	—	—
CONVEYANCE LOSSES	—	—	—	—	—
TOTAL	1081	1180	1200	1230	150
DEPENDABLE WATER SUPPLY					
LOCAL SURFACE WATER DEVELOPMENT	368	370	375	375	10
IMPORTS BY LOCAL WATER AGENCIES	2	2	2	2	0
GROUND WATER	243	310	320	330	90
CENTRAL VALLEY PROJECT	—	—	—	—	—
OTHER FEDERAL WATER DEVELOPMENT	458	485	490	510	50
WASTE WATER RECLAMATION	9	10	10	10	—
STATE WATER PROJECT	—	—	—	—	—
TOTAL	1080	1180	1200	1230	150
GROUND WATER OVERDRAFT	—	—	—	—	—
SWP SURPLUS WATER DELIVERY	—	—	—	—	—
SHORTAGE 1/	1	—	—	—	—
RESERVE SUPPLY 2/	9	85	75	60	

Totals for 1990, 2000, 2010, and CHANGE are rounded.

1/ LOCAL URBAN

2/ KLAMATH PROJECT AND LOCAL, 1980: WARM SPRINGS PROJECT, FUTURE

NORTH COAST HYDROLOGIC STUDY AREA

Total annual net water use in the North Coast HSA is projected to increase by about 150,000 acre-feet by 2010. This increase will be supported primarily by 90,000 acre-feet of ground water. Lake Sonoma, a federal facility in Sonoma County, and other federal projects in Siskiyou and Modoc Counties will supply another 50,000 acre-feet. The remainder will come from local surface supplies. The reserve supply shown for this HSA is primarily from Warm Springs Dam and Reservoir (Lake Sonoma). Yield from the reservoir will probably not be fully used until after 2010.

As discussed in Chapter III, the nature of irrigated agriculture in Siskiyou and Modoc Counties has changed considerably in the last ten years due to the increased development of ground water. This has brought modern irrigation systems into an area that before had typically been irrigated by the wild flood technique, which relies on streamflow when it is available. Now, with water available for the full growing season, crop production has increased. If ground water pumping costs do not become prohibitive, more of the same kind of development can be expected.

Some of the prospects for, and impacts of, increased ground water use and other water-related topics in specific locations within the North Coast HSA are discussed in the following sections.

Butte Valley

Ground water pumping is still increasing in Butte and Red Rock Valleys, almost entirely for the production of alfalfa. A new alfalfa pelletizing mill has been constructed and is operating in Red Rock Valley. Future alfalfa production will be a function of prices and energy costs. Historically, alfalfa raised in this region has brought higher-than-average prices because of its high protein content. The costs of energy used for pumping ground water could become a constraint in the future.

Shasta Valley

Increased ground water pumping in the Big Springs and Little Shasta River area is probably starting to impair flows in the Shasta River. Big Springs artesian flow has been diminishing over the past few years. Water use on the many new residential farms (2- to 20-acre "ranchettes") in the juniper lands east of Big Springs also may be impairing Shasta River flows.

Scott Valley

Over the past 10 years or so, irrigation development, together with increases in ground water pumping, has so increased that no flow can be observed in the Scott River in the northern portion of the valley in late summer. Available valley lands and the water supply to irrigate them are essentially in equilibrium today. This leaves little water for salmon and steelhead production, which is the major problem facing this area. Methods of augmenting flows for instream

uses, such as improving irrigation efficiency, developing additional storage, or relocating points of surface water diversion to improve flows in critical stretches of the river are being studied.

Trinity River

Major water problems on the main stem of the Trinity River are related to inadequate fish flows below Trinity Lake. Decline in salmon and steelhead runs are blamed on large-scale transbasin diversions of Trinity River water to the Sacramento Valley to meet CVP demands, along with increased siltation caused by poor logging and road building practices. Flow reregulation and watershed and spawning gravel improvement are the major local issues currently under negotiation in the region. Construction of a debris dam on Grass Valley Creek should greatly improve the situation, especially if it is augmented by some sand dredging in the Trinity River.

Humboldt Bay Region

Water supply and use in this region are essentially in balance. The major water purveyor, Humboldt Bay Municipal Water District, has nearly reached the limit of its ability to meet increasing future needs with its water supply from the lower Mad River. Upstream storage options are limited and costly. Existing supplies may be stretched through institutional arrangements with the pulp paper industries so that they can reduce water use by using more chemical reagents in the pulp bleaching process. Conjunctive use of surface and ground water in the Mad River Basin may provide some assistance.

Mendocino Coast

Very little irrigated agriculture remains on the Mendocino Coast. Water use is restricted mainly to residential use and a few industrial uses, such as the sawmill at Ft. Bragg. The major water problems exist where residential users and small communities such as Mendocino and Albion extract ground water from the coastal terraces. Aquifers on the shallow terraces produce limited amounts of water, some of it of poor quality because of high sulfide and iron levels. Few deep alluvial ground water bodies are present in this area.

Russian River

With the availability of water from Warm Springs Dam and Reservoir (Lake Sonoma) in 1984, the major water supply problems in the lower Russian River area will be solved. That supply should meet the needs in the lower Russian River beyond 2010. The remaining major water problem concerns the stretch of the Russian River above Dry Creek.

Lake Mendocino supplies water to agricultural and urban users in Mendocino, Sonoma, and Marin Counties, and for instream requirements in the Russian River. Pacific Gas and Electric Company (PGandE) has filed an application with the Federal Energy Regulatory Commission (FERC) for relicensing of the Potter Valley Project, owned and operated by PGandE. The project diverts water from the Eel River through a tunnel and the Potter Valley Power Plant into the East Fork Russian River. The water then flows into Lake Mendocino. Humboldt County, the Department of Fish and Game, and the Department of Water Resources requested FERC to require greater flows in the Eel River to improve the fisheries in the basin. This would reduce the flows diverted into the Russian River. (Recommended operation schedules are described in *Eel-Russian River Streamflow Augmentation,* Bulletin 105-5, published by the Department of Water Resources in 1976.) At a settlement conference led by FERC in May 1979, all parties accepted an interim schedule of minimum flows to be released down the Eel River below Cape Horn Dam for a three-year study period. The proposed flows were lower than those proposed by the Department in Bulletin 105-5 but higher than previous PGandE releases. During the three-year period, beginning on November 1, 1979, the parties analyzed the effects of the increased flows on the Eel River fishery and the effects of reduced flows on the Russian River water supply. A final report on the Eel River fishery studies was published in December 1982.

After extensive negotiations, the parties agreed to a permanent flow schedule and, in November 1982, filed a proposed settlement agreement with the Administrative Law Judge for the FERC. The judge certified the settlement agreement in May 1983 and submitted it to FERC staff for final review before issuance of the license.

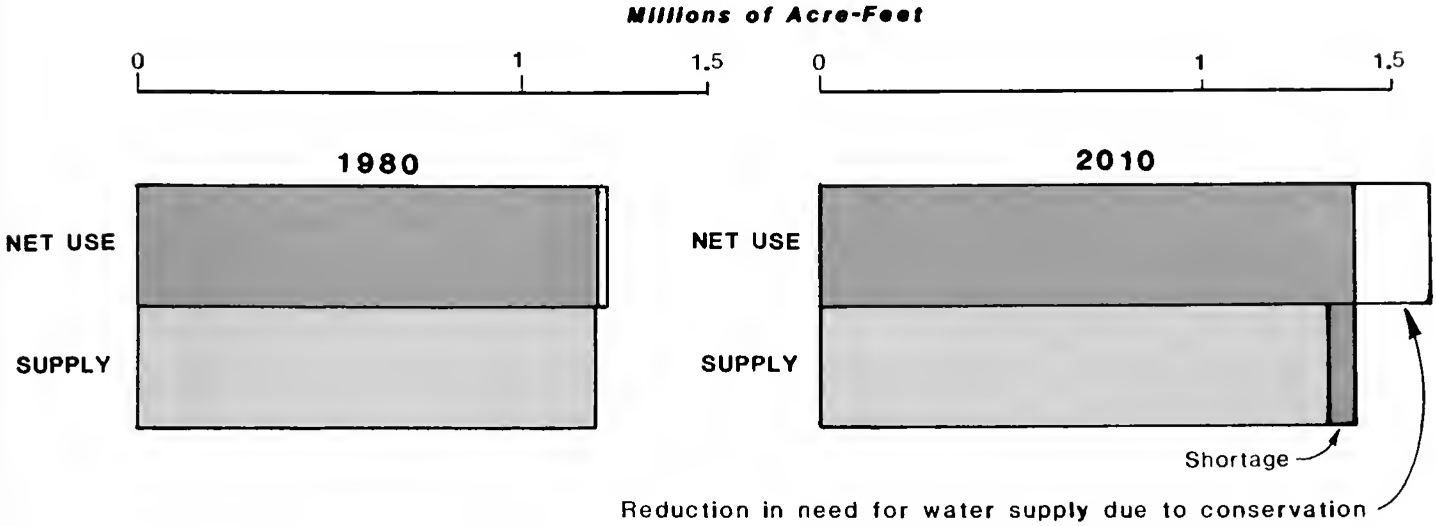
Additional issues of concern:

- Lake Mendocino's recreation use has become an important factor in Mendocino County's economy. The reservoir level in Lake Mendocino is drawn down as a result of diversions and instream requirements in the Russian River. Urban and agricultural water diverters, recreational users, and the fishery are all competing for a limited supply of water in dry years. The problem may be intensified, if less water is diverted from the Eel River to the Russian River.

- The Santa Rosa Plain remains the principal area of ground water use in the Russian River basin. This basin is generally in hydrologic balance, although the distribution of ground water pumpage throughout the basin is not uniform, indicating a need for further ground and surface water management planning, particularly in light of anticipated municipal and industrial use and availability of supplies from Lake Sonoma.

Figure 58. SURFACE WATER PROJECTS–
SAN FRANCISCO BAY HYDROLOGIC STUDY AREA

Figure 59. WATER SUPPLY AND USE SUMMARY
SAN FRANCISCO BAY HYDROLOGIC STUDY AREA 1980-2010



Thousands of acre-feet

NET WATER USE	1980	1990	2000	2010	CHANGE 1980-2010
IRRIGATION	121	110	100	90	-30
URBAN	967	1050	1090	1170	200
WILDLIFE AND RECREATION	96	100	100	100	—
ENERGY PRODUCTION	6	2	15	15	10
CONVEYANCE LOSSES	14	15	20	20	10
TOTAL	1204	1275	1325	1395	190
DEPENDABLE WATER SUPPLY					
LOCAL SURFACE WATER DEVELOPMENT	228	228	228	228	0
IMPORTS BY LOCAL WATER AGENCIES	454	460	445	455	—
GROUND WATER	211	220	220	220	10
CENTRAL VALLEY PROJECT	81	120	160	210	130
OTHER FEDERAL WATER DEVELOPMENT	56	60	60	60	—
WASTE WATER RECLAMATION	10	10	10	15	10
STATE WATER PROJECT	150	125	140	140	-10
TOTAL	1190	1225	1260	1330	140
GROUND WATER OVERDRAFT	7	20	—	—	-10
SWP SURPLUS WATER DELIVERY	7	—	—	—	-10
SHORTAGE 1/	—	30	65	65	70
RESERVE SUPPLY 2/	138	110	190	220	

Totals for 1990, 2000, 2010, and CHANGE are rounded.

1/ SWP SOUTH BAY AQUEDUCT SERVICE AREA

2/ IMPORTS BY LOCALS AND CVP; WARM SPRINGS PROJECT

SAN FRANCISCO BAY HYDROLOGIC STUDY AREA

Total annual net water use in the San Francisco Bay HSA is projected to increase by about 190,000 acre-feet by 2010, reflecting continued urban growth. By 2010, urban uses will account for about 85 percent of total net water use. Although agricultural net water use is expected to decline somewhat because of urban encroachment on irrigated land (mostly in the South Bay area), it will still be significant—about 90,000 acre-feet annually.

The increase in use by 2010 will be partially supported by an additional import of 130,000 acre-feet from the CVP (the San Felipe Division). Essentially no change is projected in total annual net use of ground water. SWP water delivered through the North Bay and South Bay Aqueducts is expected to total 140,000 acre-feet in 2010. In the absence of adequate future water supply facilities to augment the existing yield of the SWP, shortages in the amount of 65,000 acre-feet will most likely occur. Water transfers and exchanges could offset the effects of these shortages.

North Bay

When Phase II of the North Bay Aqueduct is completed in the mid-1980s, the total water supply of the North Bay area will be more than adequate to meet projected needs beyond 2010. However, a problem of water supply distribution will exist in Napa County. Conveyance facilities will be too costly to permit communities in the northern part of the county to obtain water from the North Bay Aqueduct, which terminates in the southern part of the county. As an alternative, a local plan is being devised that will allow SWP entitlements and northern Napa County surface water to be exchanged between the cities of Calistoga and Napa.

Other water management problems include:

- Lack of a more complete evaluation of the ground water resources in the Napa Valley.
- Need to determine the water quality and quantities for achieving a desirable ecological balance in the Suisun Marsh and means of implementing the balance.

South Bay

The Department of Water Resources has been conducting planning studies to determine when supplemental water is needed in this area and to evaluate the potential for increasing the effectiveness of existing and future supplies through pooling or exchanges by interconnection of delivery systems and adjustments of service areas.

Although the South Bay may have sufficient water supplies on a regional basis beyond 2010, certain areas have been identified that will have supplemental water needs in excess of current reserve supplies. However, if local water agencies cooperate in improvement of the overall delivery systems, these supplemental needs can be met, and new water supply projects will not be required until after 2010.

Water management problems and issues in the area include:

- Alameda County Water District will have supplemental water needs in excess of current reserve supplies, beginning about 2000. Alternatives available include an increase in deliveries from the San Francisco Water Department (SFWD), surplus local water supplies from the Alameda County Flood Control and Water Conservation District, Zone 7, or SWP entitlement exchanges between Zone 7 and the Santa Clara Valley Water District.
- Deliveries under East Bay Municipal Utility District's (EBMUD) contract with the U.S. Bureau of Reclamation (USBR) for deliveries from the Folsom South Canal have been included as a part of EBMUD's future available water supplies. Not all of this supply is projected to be required by EBMUD before 2010.
- With completion of the San Felipe Division of the CVP (scheduled for 1987) water management problems—especially ground water overdraft and land subsidence in Santa Clara County—will be alleviated.
- SFWD has proposed construction of a fourth barrel of the Hetch Hetchy Aqueduct to transport the full yield of San Francisco's Sierra Nevada reservoirs to the Bay area. SFWD's projections indicate that supplemental water needs will equal current reserve supplies shortly before 2000. Their projections also indicate that, shortly before 1990, the existing system for importing the water from the Sierra Nevada reservoirs will be inadequate to meet peak daily demands. Projections by the Department of Water Resources, however, do not indicate that SFWD will need additional delivery capacity until beyond 2010.

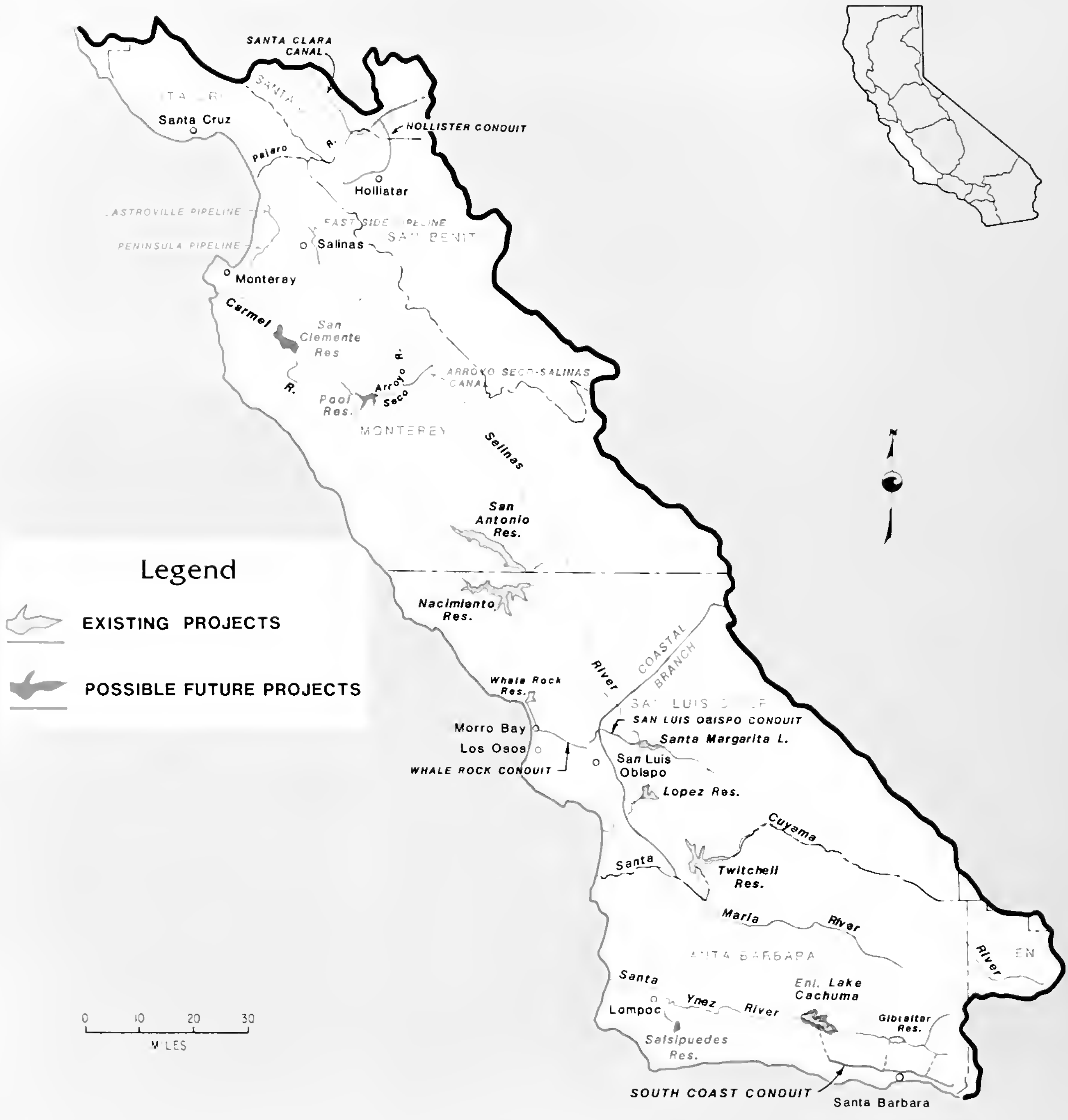
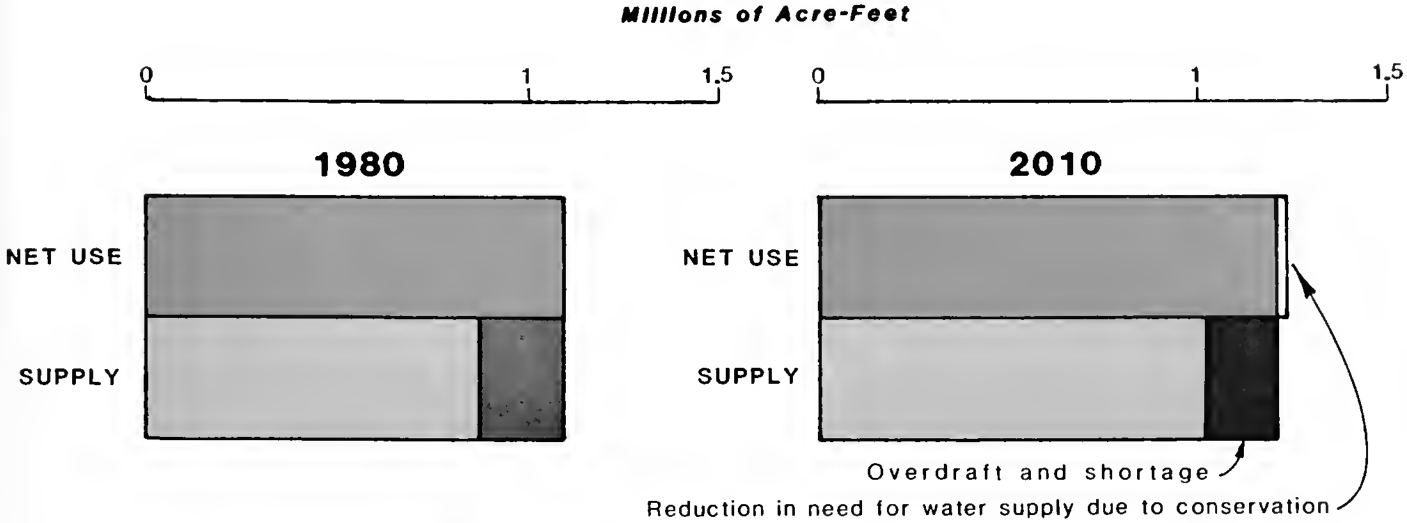


Figure 60. SURFACE WATER PROJECTS–
CENTRAL COAST HYDROLOGIC STUDY AREA

Figure 61. WATER SUPPLY AND USE SUMMARY
CENTRAL COAST HYDROLOGIC STUDY AREA 1980-2010



(Thousands of acre-feet)

NET WATER USE	1980	1990	2000	2010	CHANGE 1980-2010
IRRIGATION	902	940	940	930	30
URBAN	188	210	230	250	60
WILDLIFE AND RECREATION	2	5	5	5	—
ENERGY PRODUCTION	7	15	15	10	—
CONVEYANCE LOSSES	—	5	5	5	10
TOTAL	1099	1175	1195	1200	100
DEPENDABLE WATER SUPPLY					
LOCAL SURFACE WATER DEVELOPMENT	39	54	54	54	10
IMPORTS BY LOCAL WATER AGENCIES	—	—	—	—	—
GROUND WATER	768	768	768	768	0
CENTRAL VALLEY PROJECT	—	40	60	70	70
OTHER FEDERAL WATER DEVELOPMENT	54	54	54	54	0
WASTE WATER RECLAMATION	9	30	30	30	20
STATE WATER PROJECT	0	40	40	40	40
TOTAL	870	985	1005	1015	140
GROUND WATER OVERDRAFT	224	180	180	175	-50
SWP SURPLUS WATER DELIVERY	—	—	—	—	—
SHORTAGE	5	10	10	10	10
RESERVE SUPPLY 2/	17	0	0	0	

Totals for 1990, 2000, 2010, and CHANGE are rounded.

1/ LOCAL URBAN SUPPLIES, 1980: SWP, FUTURE

2/ NACIMIENTO RESERVOIR AND SWP

CENTRAL COAST HYDROLOGIC STUDY AREA

Total annual net water use in the Central Coast HSA is projected to increase by about 100,000 acre-feet by 2010. The Monterey Bay area will use 70,000 acre-feet, of which 40,000 acre-feet will represent urban net water use. Nearly all the 20,000-acre-foot increase in San Luis Obispo and Santa Barbara Counties will support urban use.

The entire increase in net water use in the Monterey Bay area will be satisfied by imports from the federal San Felipe Division of the CVP. The increase in San Luis Obispo and Santa Barbara Counties was assumed to be met by construction of the distribution facilities from Nacimiento Reservoir and the State Water Project's Coastal Branch Aqueduct or local alternatives.

The Monterey County Flood Control and Water Conservation District completed construction of Nacimiento Dam and Reservoir in 1958. The reservoir has a capacity of 350,000 acre-feet and a yield of 85,000 acre-feet per year, much of which is released to the Salinas River for ground water recharge. In 1959, an agreement between the counties of Monterey and San Luis Obispo gave San Luis Obispo County an annual entitlement to 17,500 acre-feet. The county is presently diverting about 2,400 acre-feet for use near the reservoir, but it has not yet built a distribution system to deliver water to other areas. San Luis Obispo County officials scheduled an election on a bond issue to finance construction of such a system for November 1980, but the board of supervisors decided to postpone the election.

Santa Barbara County has asked the Department of Water Resources to determine whether Gibraltar Reservoir and Cachuma Reservoir enlargement, Camuesa Canyon Dam construction, and Santa Barbara Wastewater Reclamation are eligible for funding as part of the State Water Project. Santa Barbara County has reduced its entitlement from the SWP and is pursuing local projects as an alternative to the Coastal Aqueduct. It will be able to meet its water requirements through a combination of local projects, and remaining supply from the Coastal Aqueduct.

Following are highlights of the major water management issues and examples of some with more limited impact in the HSA.

Monterey, San Benito, and Santa Cruz Counties

Precipitation is highly variable, and most ground water basins are relatively small in the northern part of the Central Coast HSA. This causes large variation in water supplies from year to year, with resultant large changes in ground water levels. Severe short-term water shortages can occur during years of drought. In addition, some ground water basins are already in an overdraft condition.

To support the growing water needs and alleviate the overdraft in these counties, the water supply to certain parts of the area must be increased. This may be accomplished by developing local supplies or by importing water.

Specific areas where problems exist and some of the possible solutions are discussed in the following sections.

Salinas Valley. The present hydrologic balance indicates a total overdraft of about 60,000 acre-feet per year in the Salinas Valley, a substantial increase over the 16,000 acre-feet of annual overdraft that occurred during the 1969–1975 period. On the valley's east side, where there is little natural ground water recharge, pumping lowers the ground water levels and causes large subsurface flows from the western side. This, together with excessive pumping in the western region, has lowered the ground water table below sea level near the coast, and sea water is intruding into the ground water basin.

A project formulated to alleviate these problems was endorsed by Monterey County in September 1982. Project features include: (1) a dam on Arroyo Seco River at the Pools Reservoir site with a capacity of 100,000 acre-feet; (2) a 4.7-megawatt power plant at the dam; (3) an Arroyo Seco-Salinas Conveyance Canal for delivery of the water to the Salinas River; (4) a Castroville Pipeline; and (5) an East Side Pipeline. Project features are shown on Figure 60. The reservoir would have an annual yield of 43,000 acre-feet and provide flood control and recreation benefits. Energy production is estimated at 19 million kilowatthours annually. Project costs are estimated to be approximately $80 million at December 1981 prices.

Water deliveries to the East Side service area would alleviate ground water overdraft. Deliveries to the Castroville service area would reduce ground water extractions and sea-water intrusion.

Monterey Peninsula and Carmel Valley. The municipal and industrial demands of the Monterey Peninsula, which far exceed the local ground water supply, are met by imported surface and ground water from Carmel Valley. The present hydrologic balance indicates a small overdraft of about 2,000

acre-feet per year in the Monterey Peninsula and 2,000 acre-feet per year in the Carmel Valley. Sea-water intrusion has also been identified in the vicinity of Marina.

The potential exists for further development of the Carmel River, where an average of 70,000 acre-feet per year flows to the ocean. Presently, water is stored in two small reservoirs; however, there are no major reserve supplies to be drawn on in the event of a drought. During the drought of 1976 and 1977, severe shortages occurred, and water rationing was instituted on the Monterey Peninsula. In the future, as population grows and water needs increase, the development of an additional supply from waste water reclamation or surface storage will assume even greater importance, even with strong water conservation programs.

To meet these needs, the Monterey Peninsula Water Management District is currently proposing the enlargement of San Clemente Reservoir to increase its active storage capacity to 27,000 acre-feet. If voter approval is obtained, construction could begin by 1986.

The District has also approved a ground water recharge project in Seaside, east of Monterey, that would convey excess flows from the Carmel River in wet years to local recharge basins.

Elkhorn Slough and Pajaro Valley. Overdrafts of about 4,000 acre-feet per year in the Elkhorn Slough area and about 16,000 acre-feet per year in the Pajaro Valley were estimated for 1980. This overdraft has reversed the natural seaward gradient of the ground water table, and sea-water intrusion is occurring in both areas for several miles on each side of the mouth of the Pajaro River. Increasing water use in the future will worsen the situation, unless new supplies are developed or the overdraft is curtailed. The Pajaro ground water basin has been defined by the Department as a basin subject to critical conditions of overdraft.

South Santa Clara, Hollister, and San Juan Valleys. Extensive agricultural development has resulted in a present overdraft of about 28,000 acre-feet per year. This is a significant increase from the 11,000-acre-foot annual overdraft calculated in the hydrologic balance for the 1969–1975 period. In addition, pumping has been limited in some parts of eastern Hollister Valley by concentrations of boron and chloride in the ground water that limit its suitability for agricultural use.

A supply of imported water will become available to the area when the San Felipe Division of the Central Valley Project is completed. Much of the imported water will be used to recharge the ground water basin. Surface water will be delivered to replace poor-quality ground water in the Hollister Valley.

San Luis Obispo County

City of Morro Bay. During the past 25 years, the city of Morro Bay has frequently rationed water, and, since 1976, has had an active water conservation program. Based on studies that indicated water shortages in Morro Bay would continue, the State Coastal Commission imposed a building moratorium in 1978. Recently, a study by the Department showed that the problem is not one of supply but rather of location and number of wells. Nevertheless, facilities to increase recharge of the ground water basins and to import additional water will be necessary to ensure adequate supplies of good quality water will be available.

Los Osos—Baywood Park Area. This area, situated 4 miles south of Morro Bay, obtains its water from the underlying ground water basin. The population of this area is growing rapidly. As urban growth continues, central waste water treatment facilities may be needed to replace septic tanks and protect ground water quality. Additional water will be needed in the future.

City of San Luis Obispo. Projections of water use by the city of San Luis Obispo indicate that the city's dependable water supply will not satisfy all needs by the mid-1980s. Salinas Reservoir, in the Upper Salinas Valley, is one of the city's water sources. Negotiations are under way to enlarge the reservoir's capacity, but the city of San Luis Obispo and the communities in the northern portion of the county have not resolved related water rights issues.

Santa Barbara County

South Coast Area. The south coast area, including the communities of Carpinteria, Summerland, Santa Barbara, and Goleta, is water-deficient. The area is predominantly urban, with limited ground water sources and fixed entitlements to surface water supplies. Additional sources of water are needed to curtail overdrafting of the ground water basin and to meet supplemental needs, should further urban growth take place.

San Antonio Basin. In this basin, which lies between the Santa Maria and Santa Ynez Valleys, water use by Vandenberg Air Force Base and irrigated agriculture exceeds the supply from existing sources. The base has expressed interest in obtaining water from the State Water Project. The amount needed and the extent to which additional conservation and reclamation could reduce needs have not been determined, but may be significant.

Lompoc Area. Although present use in the Lompoc ground water basin is estimated to exceed supply by about 3,000 acre-feet per year, the ground water levels remain near the surface along the Santa Ynez River near Lompoc, with only relatively small

amounts of vacant storage space available. Moreover, the ground water supply in the zone with available storage space is high in total hardness and total dissolved solids. In the city of Lompoc, all water is softened in a municipal plant. Use of home water softeners adds to the problem by increasing the total dissolved solids in water returning to the ground water basin. Salsipuedes Dam and Reservoir Project on Salsipuedes Creek, a major tributary of the Santa Ynez River, has been investigated at various times as a means of augmenting water supplies in the Lompoc area. This could be accomplished through a ground water replenishment program or by direct surface deliveries. A 50,000-acre-foot capacity reservoir could yield up to 6,500 acre-feet per year, depending on the method of operation. Estimated unit costs of water in 1982 prices range from $650–$850 per acre-foot for ground water replenishment and from $1,400–$1,900 per acre-foot for surface delivery. The location of the proposed reservoir is shown on Plate 1.

Santa Maria Valley. Although the Santa Maria Valley has a relatively large ground water basin, studies indicate that urban and agricultural use of ground water exceeds the annual rate of replenishment and that the mineral concentration is high. Therefore, additional water will be needed in the future. A conjunctive use program that makes use of the ground water basin and additional surface water supplies could increase the yield and help improve water quality.

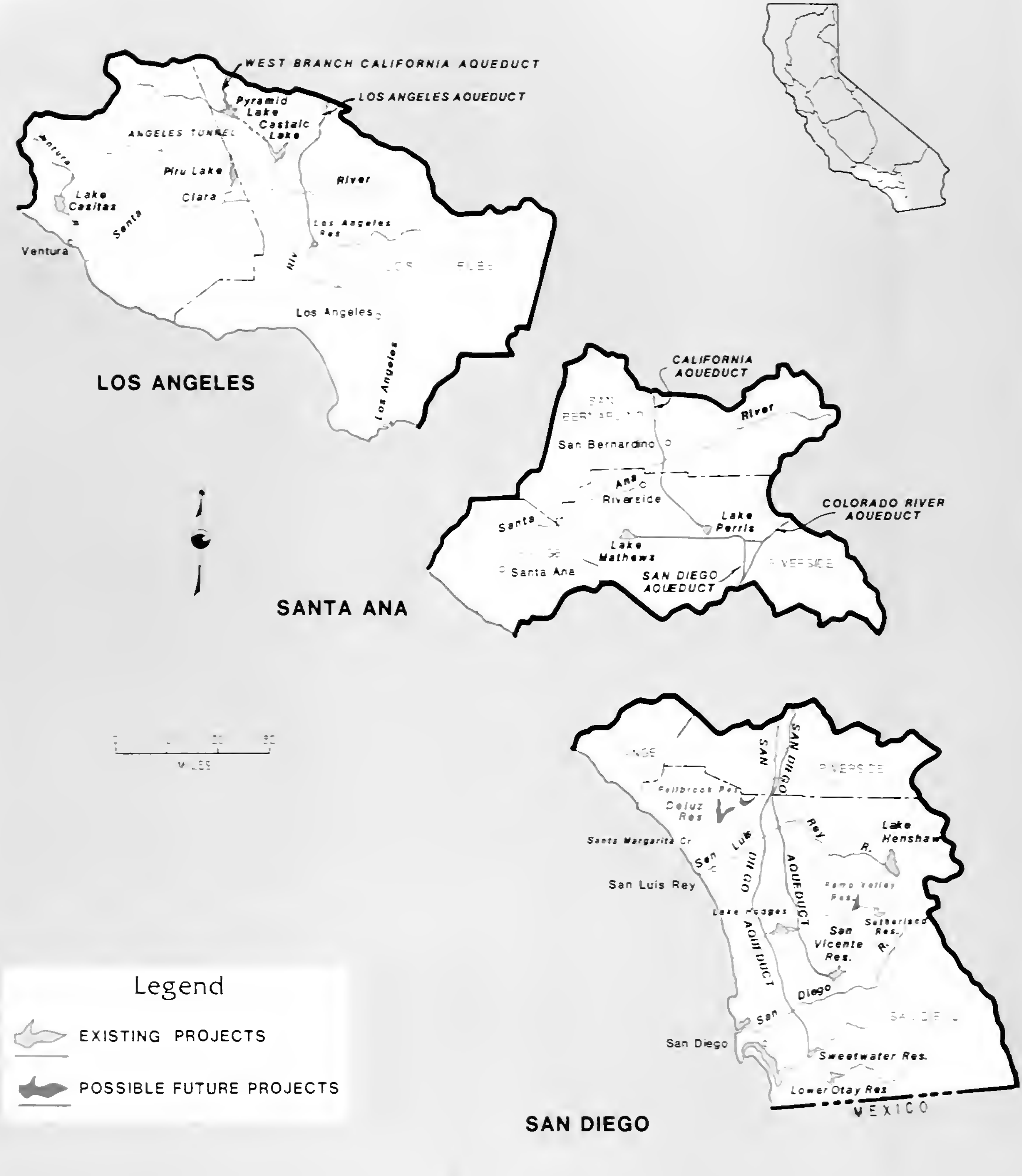


Figure 62. SURFACE WATER PROJECTS – LOS ANGELES, SANTA ANA, AND SAN DIEGO HYDROLOGIC STUDY AREAS

Table 60 WATER SUPPLY AND USE SUMMARY LOS ANGELES HYDROLOGIC STUDY AREA 1980-2010

(Thousands of acre-feet)

NET WATER USE	1980	1990	2000	2010	CHANGE 1980-2010
IRRIGATION	276	250	220	190	-90
URBAN	1534	1630	1680	1790	260
WILDLIFE AND RECREATION	8	10	15	20	10
ENERGY PRODUCTION	7	30	25	20	10
CONVEYANCE LOSSES	81	75	75	75	—
TOTAL	1906	1995	2015	2095	190
DEPENDABLE WATER SUPPLY					
LOCAL SURFACE WATER DEVELOPMENT	29	29	29	29	0
IMPORTS BY LOCAL WATER AGENCIES	752	640	640	640	-110
GROUND WATER	483	483	483	483	0
CENTRAL VALLEY PROJECT	—	—	—	—	—
OTHER FEDERAL WATER DEVELOPMENT	20	20	20	20	0
WASTE WATER RECLAMATION	59	100	195	265	210
STATE WATER PROJECT	481	600	590	590	110
TOTAL	1824	1870	1955	2030	210
GROUND WATER OVERDRAFT	82	—	—	—	-80
SWP SURPLUS WATER DELIVERY	—	—	—	—	—
SHORTAGE 1/	—	125	60	65	60
RESERVE SUPPLY 2/	164	—	—	—	

Table 61 WATER SUPPLY AND USE SUMMARY SANTA ANA HYDROLOGIC STUDY AREA 1980-2010

(Thousands of acre-feet)

NET WATER USE	1980	1990	2000	2010	CHANGE 1980-2010
IRRIGATION	320	290	250	220	-100
URBAN	586	710	800	910	320
WILDLIFE AND RECREATION	2	10	10	10	10
ENERGY PRODUCTION	9	—	—	—	-10
CONVEYANCE LOSSES	45	40	40	40	—
TOTAL	962	1050	1100	1180	220
DEPENDABLE WATER SUPPLY					
LOCAL SURFACE WATER DEVELOPMENT	93	93	93	93	0
IMPORTS BY LOCAL WATER AGENCIES	290	120	120	120	-170
GROUND WATER	402	402	402	402	0
CENTRAL VALLEY PROJECT	—	—	—	—	—
OTHER FEDERAL WATER DEVELOPMENT	—	—	—	—	—
WASTE WATER RECLAMATION	29	50	70	80	50
STATE WATER PROJECT	138	385	400	400	260
TOTAL	952	1050	1085	1095	140
GROUND WATER OVERDRAFT	10	—	—	—	-10
SWP SURPLUS WATER DELIVERY	—	—	—	—	—
SHORTAGE 1/	—	—	15	85	90
RESERVE SUPPLY 2/	203				

1/ SWP, BASED ON FIGURE 48 2/ SWP Totals for 1990, 2000, 2010, and CHANGE are rounded.

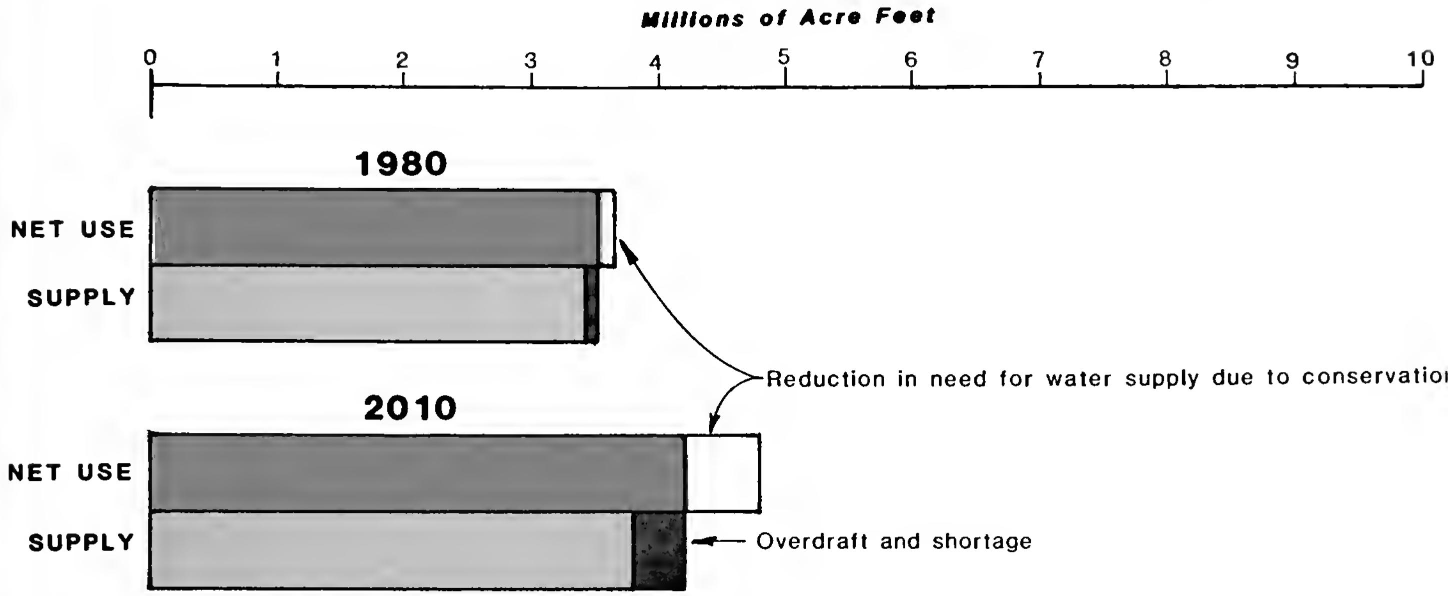
Table 62 WATER SUPPLY AND USE SUMMARY
SAN DIEGO HYDROLOGIC STUDY AREA 1980-2010

(Thousands of acre-feet)

NET WATER USE	1980	1990	2000	2010	CHANGE 1980-2010
IRRIGATION	198	190	180	170	-30
URBAN	389	480	580	670	280
WILDLIFE AND RECREATION	7	10	10	10	—
ENERGY PRODUCTION	—	—	—	—	—
CONVEYANCE LOSSES	40	35	35	40	—
TOTAL	634	715	805	890	250
DEPENDABLE WATER SUPPLY					
LOCAL SURFACE WATER DEVELOPMENT	37	37	37	37	0
IMPORTS BY LOCAL WATER AGENCIES	290	215	215	215	-80
GROUND WATER	77	77	77	77	0
CENTRAL VALLEY PROJECT	—	—	—	—	—
OTHER FEDERAL WATER DEVELOPMENT	—	—	—	—	—
WASTE WATER RECLAMATION	9	40	50	55	50
STATE WATER PROJECT	221	255	245	245	20
TOTAL	634	625	625	630	0
GROUND WATER OVERDRAFT	—	—	—	—	—
SWP SURPLUS WATER DELIVERY	—	—	—	—	—
SHORTAGE 1/		90	180	260	260
RESERVE SUPPLY 2/	46	—	—	—	

1/ SWP, BASED ON FIGURE 48 2/ SWP Totals for 1990, 2000, 2010, and CHANGE are rounded.

Figure 63. WATER SUPPLY AND USE SUMMARY LOS ANGELES, SANTA ANA, AND SAN DIEGO HYDROLOGIC STUDY AREAS 1980-2010



Thousands of acre-feet

NET WATER USE	1980	1990	2000	2010	CHANGE 1980-2010
IRRIGATION	794	730	650	580	-210
URBAN	2509	2820	3060	3370	860
WILDLIFE AND RECREATION	17	30	35	40	20
ENERGY PRODUCTION	16	30	25	20	–
CONVEYANCE LOSSES	166	150	150	155	-10
TOTAL	3502	3760	3920	4165	660
DEPENDABLE WATER SUPPLY					
LOCAL SURFACE WATER DEVELOPMENT	159	159	159	159	0
IMPORTS BY LOCAL WATER AGENCIES	1332	975	975	975	-360
GROUND WATER	962	962	962	962	0
CENTRAL VALLEY PROJECT	—	—	—	—	—
OTHER FEDERAL WATER DEVELOPMENT	20	20	20	20	0
WASTE WATER RECLAMATION	97	190	315	400	300
STATE WATER PROJECT	840	1240	1235	1235	400
TOTAL	3410	3545	3665	3755	340
GROUND WATER OVERDRAFT	92	—	—	—	-90
SWP SURPLUS WATER DELIVERY	—	—	—	—	—
SHORTAGE 1/	0	215	256	410	410
RESERVE SUPPLY 2/	413	0	0	0	

Totals for 1990, 2000, 2010, and CHANGE are rounded.

1/ SWP, BASED ON FIGURE 48

2/ SWP

Los Angeles Times photo

SOUTH COASTAL REGION (LOS ANGELES, SANTA ANA, AND SAN DIEGO HYDROLOGIC STUDY AREAS)

Total increase in average annual net water use from 1980 to 2010 in the South Coastal region is projected to be about 660,000 acre-feet. Agricultural net water use will decrease by about 210,000 acre-feet by 2010 because of urban expansion onto irrigated lands. Urban net water use will increase by about 860,000 acre-feet by then.

The additional 1,020,000 acre-feet of water supply required is much larger than the increase in total net water use, because the mandated reduction of water imported from the Colorado River will reduce supplies about 360,000 acre-feet per year below present levels of use. No cooling water use was projected from these supplies by 2000. The SWP is expected to provide 400,000 acre-feet of additional supplies. Additional waste water reclamation was projected to provide about 300,000 acre-feet. Assuming prolonged delays in providing additional water supplies for the SWP, shortages in dependable supplies are projected to reach 410,000 acre-feet per year by 2010.

The total increase in net water use for the region reflects the effect of water conservation measures implemented between 1980 and 2010. These measures result in a reduction in need for water supplies in 2010 of 375,000 acre-feet per year. By 1980, conservation efforts had reduced annual water supply needs by an estimated 140,000 acre-feet below the level it would otherwise have reached.

The major water management issues are discussed in the following sections.

City of Los Angeles

About 80 percent of the city's present water supply —467,000 acre-feet per year—is obtained from the Owens Valley-Mono Lake area. This supply could be significantly reduced if the courts rule against the city in the litigation related to the export of water from Mono Lake and the Owens Valley. Should this occur, the city would have to increase the supply obtained from The Metropolitan Water District of Southern California (MWD). This would be in addition to the 660,000 acre-feet of additional supply that the entire South Coastal region is expected to need by 2010.

Oxnard Plain

In the Oxnard Plain area of Ventura County, ground water pumping for both urban and agricultural uses has created sea-water intrusion problems in the Ventura Central ground water basin. The basin has been designated by the Department of Water Resources as subject to critical conditions of overdraft. A physical plan involving ground water basin management has been developed to control that problem, and an assessment district has been formed to finance the plan. The Department and the State Water Resources Control Board (SWRCB) will continue to monitor the situation.

Upper Santa Ana Area

A local agency proposal to increase its use of Colorado River water has been approved by SWRCB. The plan changes the method of averaging limitations of the total dissolved solids in the effluent at certain waste water treatment plants. This would allow for optimum use of Colorado River water in the basin.

MWD and the Department are jointly funding a feasibility study, in cooperation with the Chino Basin Municipal Water District, to develop a ground water basin storage program in conjunction with the SWP and local facilities. A similar study involving the San Bernardino Valley Municipal Water District and the San Gorgonio Pass Water Agency is also being conducted for some other areas.

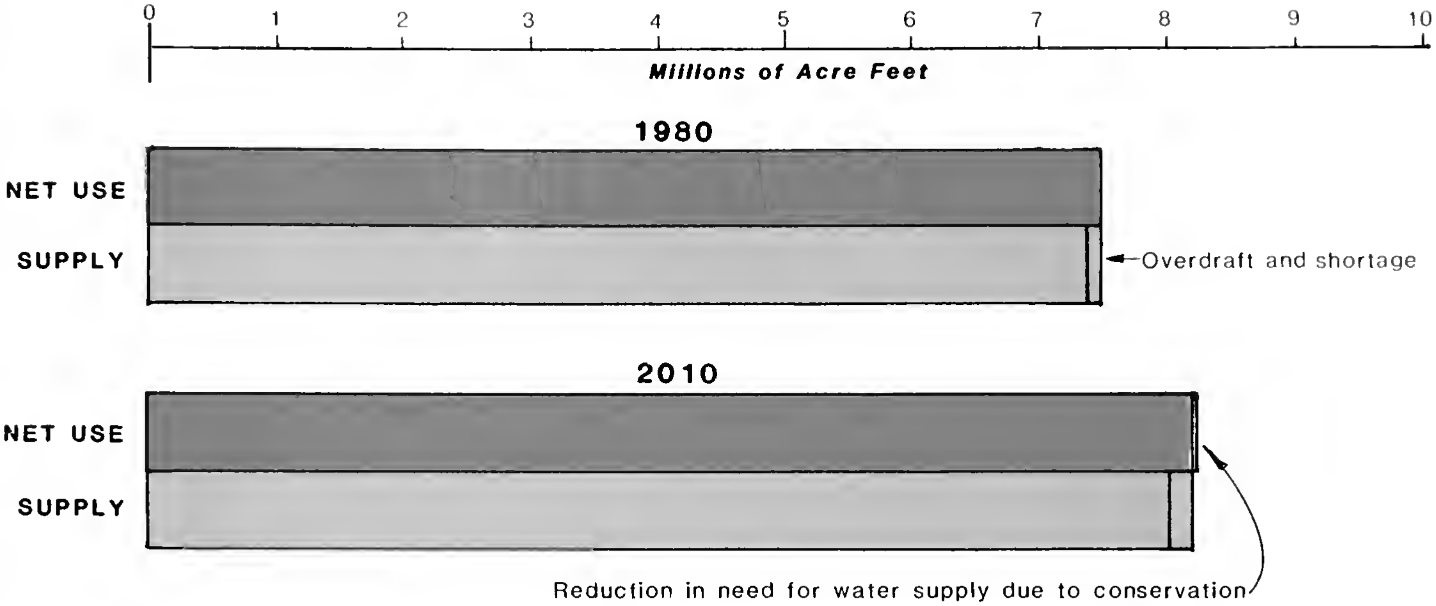
San Diego County

Because of low rainfall and limited ground water supply, the county relies heavily on imported water to meet its requirements. Therefore, any interruption of imported water supplies would be critical to the area. Various public agencies within the county have embarked on a variety of programs to help bridge the gap between future uses and supplies.

Renewed interest has also been expressed in the construction of the Santa Margarita Project in northern San Diego County. The project, which would consist of Fallbrook Dam and DeLuz Dam on the Santa Margarita River, and associated distribution facilities, would provide flood control and supplemental water supplies to the Fallbrook Public Utility District and the Marine Corps base at Camp Pendleton. The U.S. Bureau of Reclamation is currently (1982) updating the feasibility report and the Environmental Impact Statement on the project to reflect local conditions that have changed since the original reports were completed in 1969. Legislation has been introduced in Congress to authorize construction of the project.

Figure 64. SURFACE WATER PROJECTS – SACRAMENTO HYDROLOGIC STUDY AREA

Figure 65. WATER SUPPLY AND USE SUMMARY SACRAMENTO HYDROLOGIC STUDY AREA 1980-2010



Thousands of acre-feet

NET WATER USE	1980	1990	2000	2010	CHANGE 1980-2010
IRRIGATION	6682	7030	7010	7140	460
URBAN	493	590	660	730	240
WILDLIFE AND RECREATION	160	165	165	165	—
ENERGY PRODUCTION	—	—	—	—	—
CONVEYANCE LOSSES	129	150	150	150	20
TOTAL	7464	7935	7985	8185	720
DEPENDABLE WATER SUPPLY					
LOCAL SURFACE WATER DEVELOPMENT	2866	2950	2960	3010	140
IMPORTS BY LOCAL WATER AGENCIES	9	9	9	9	0
GROUND WATER	1798	1870	1900	1930	130
CENTRAL VALLEY PROJECT	2422	2710	2715	2760	340
OTHER FEDERAL WATER DEVELOPMENT	259	270	270	270	10
WASTE WATER RECLAMATION	17	20	20	25	10
STATE WATER PROJECT	—	5	10	10	10
TOTAL	7371	7835	7885	8015	640
GROUND WATER OVERDRAFT	85	70	60	120	40
SWP SURPLUS WATER DELIVERY	—	—	—	—	—
SHORTAGE 1/	8	30	40	50	40
RESERVE SUPPLY 2/	535	275	340	370	

Totals for 1990, 2000, 2010, and CHANGE are rounded.

1/ LOCAL URBAN

2/ CVP, AND LOCAL (PLACER COUNTY WATER AGENCY, YUBA COUNTY WATER AGENCY, AND OROVILLE-WYANDOTTE IRRIGATION DISTRICT).

SACRAMENTO HYDROLOGIC STUDY AREA

The total projected increase in net water use from 1980 to 2010 is about 720,000 acre-feet per year. Although ETAW increases by 730,000 acre-feet, net water use for agriculture increases by only 460,000 acre-feet because basin outflow from irrigation return flows will be substantially reduced by greater irrigation efficiency. The increased irrigation efficiency and a greater proportion of lower water-using crops will reduce agricultural applied water by about 150,000 acre-feet below 1980 levels. An increase in the average irrigation efficiency for rice from 45 percent to 55 percent will have a great effect on the total amount of applied water because of the high application rates and the large acreages involved.

The increase in total annual net water use by the urban sector in 2010 will be significant—240,000 acre-feet. That amount is about 35 percent of the total increase.

The principal source of supply to meet the increased use will be the current reserve supplies of the Central Valley Project, with an increase in use in 2010 of about 340,000 acre-feet annually over 1980 levels. Increased net use of local surface supplies and ground water will be about 140,000 and 130,000 acre-feet, respectively.

The stepped-up Central Valley Project deliveries will be provided to the southwestern part of the Sacramento Valley through the Tehama-Colusa Canal. Additional local surface water use will occur principally on the east side of the Sacramento Valley. Increased ground water use is expected to occur throughout the valley floor and in the area upstream of Shasta Lake.

Highlights of the major water management-related issues and some examples of those of more limited or local impact are presented in the following sections.

Sacramento Valley Floor

Large increases in irrigated land acreage have occurred during the past decade. These increases are related to the availability of new water supplies from the Tehama-Colusa Canal, increased use of ground water, and changes in crop patterns. In the latter case, winter-planted and spring-irrigated wheat has replaced as much as 95 percent of the formerly dry-farmed barley crop. Rice, a high water-using, relatively high income crop, has doubled in acreage. The introduction of new and higher-yielding varieties of rice and wheat and increasing domestic and foreign demand for these crops are responsible for the increased acreages.

One of the major water issues in the Sacramento Valley is local control of ground water resources. Valley farmers strongly defend their ground water basin because they feel it is threatened by those wishing to export this resource. Other major concerns are bank erosion, seepage, and recreation trespass along the Sacramento River. Declining fish runs in the Sacramento River and the Delta is another issue in the valley.

Chico Area Ground Water. The ground water basin in and around the city of Chico is recharged mostly by Big Chico, Little Chico, and Butte Creeks, which drain volcanic rock areas to the east. Some of the fairly shallow municipal wells around Chico are exhibiting nitrate levels above public health standards. Effluent from non-sewered residential development, fertilization of agricultural crops, and rainfall runoff into drainage wells located throughout the city have been blamed for this contamination. Discontinued use of high-nitrate domestic wells and drainage wells and extension of the city's sewer system will probably alleviate this problem.

Yolo-Solano Counties. Completion of Indian Valley Dam and Reservoir on North Fork Cache Creek has virtually eliminated the ground water overdraft problem in Yolo County, except in local areas, such as the Yolo-Zamora area, where Indian Valley water is not available. Both Yolo and Solano Counties will need additional water after 2000. The proposed West Sacramento Canal Unit of the CVP is the most likely source of supplemental water supplies for the area.

Upper Pit River

The number of wells in the upper Pit River basin has increased by 300 percent between 1960 and 1980. Most of this increase is for irrigating alfalfa, primarily using sprinklers. Use of large center-pivot or wheel-line sprinklers to irrigate alfalfa is now commonplace. Some of this activity has replaced acreages of meadow pasture that had been irrigated by wild flooding from surface water supplies, when they were available.

Big Valley, which relies on Pit River flows for its main water supply, is receiving less water than it

received formerly because water use is increasing in Warm Springs Valley and in the upper South and North Fork Pit River regions. Sprinkler irrigation and land leveling to improve surface irrigation of alfalfa and summer-grown grain have increased farm income substantially and changed once-pastoral valleys into fairly intensely irrigated agricultural regions. With high costs of further surface water development, future expansion of irrigation will probably rely on ground water sources. Irrigation by ground water in Fall River and Big Valley is currently being affected by ever-increasing electrical energy costs. Some farmers in Big Valley claim that 30 percent of their gross revenue from alfalfa production is needed to pay pumping energy charges. It remains to be seen whether farm income can stay abreast of costs of energy for pumping.

Shasta County

The foothill and mountain areas of eastern Shasta County have become popular sites for subdivision development. Residential water is provided almost entirely from domestic wells drilled in low-yield volcanic rock. Water supplies vary from small to practically nonexistent. The sheer number of new wells has caused existing wells to fail in summer-home areas at middle and lower elevations. Shasta County is embarking on a multi-year study to help resolve this problem.

Sierra Nevada Foothills

Rapid population growth in the Sierra Nevada foothills is taxing the developed surface and ground water supplies. Surface water systems lack adequate storage capacity. They were especially vulnerable during the 1976–77 drought, with rationing commonplace. The community of Paradise and the Nevada and El Dorado Irrigation Districts were all forced to ration water. Ground water is a very unpredictable source because of the geologic formations typical of the area, which are characterized by underlying volcanic or fractured crystalline rock. Many wells went dry during the drought. Ground water quality is a problem in some areas.

Some of the water supply problems resulting primarily from population growth in the El Dorado Irrigation District could be alleviated by the proposed Upper (Mountain) South Fork American River Project (SOFAR), which is sponsored jointly by the district and the El Dorado County Water Agency. The project consists of a diversion dam at Forni that would divert part the South Fork water through a series of reservoirs, tunnels, and powerhouses. Flow in the amount of 30,000 acre-feet would be diverted annually for urban and agricultural use, with the remaining flow returned to the South Fork near Pollock Pines. Total gross storage capacity of the project would be 199,000 acre-feet. Its total installed generat-

ing capacity would be 110 megawatts, with an average of 470 million kilowatthours of electricity produced per year. Estimated first cost of the project is about $450,000,000 at 1983 first quarter price levels.

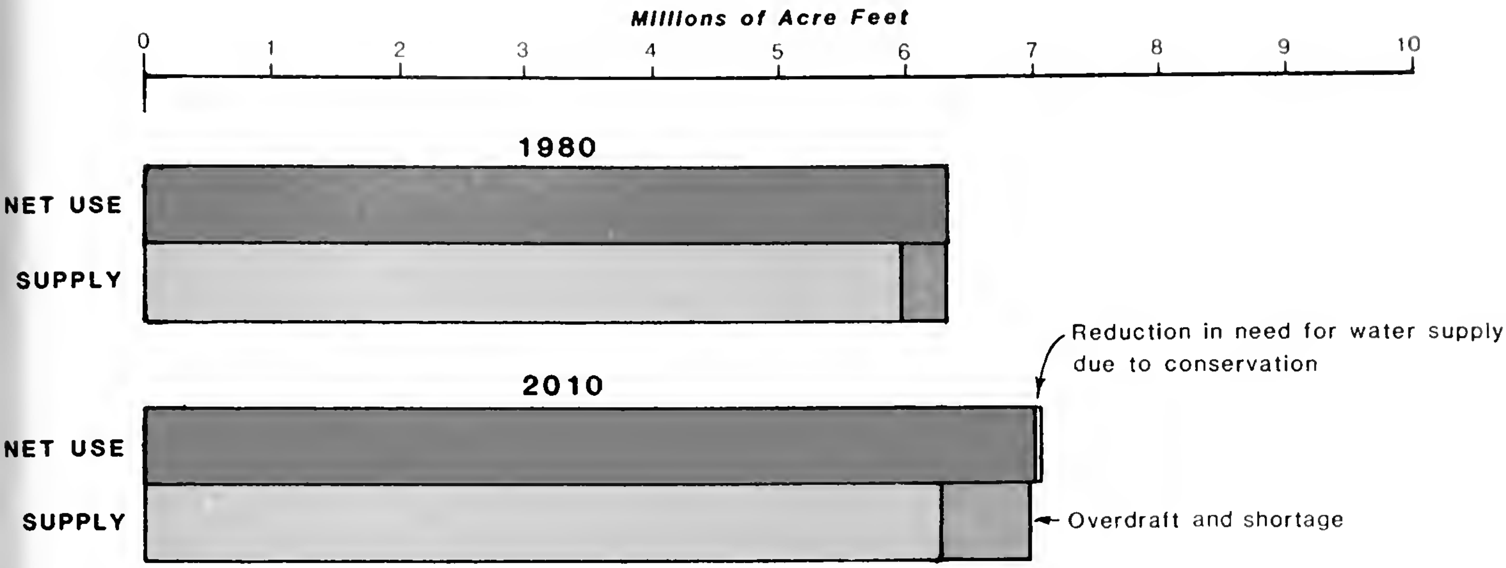
The voters of El Dorado County have authorized the issuance of up to $560 million in revenue bonds to finance construction of the project. A permit from the State Water Resources Control Board was approved in the fall of 1982 and a permit from the Federal Energy Regulatory Commission for power generation was pending at that time. Contractual commitments for the sale of energy and the ability to market bonds for construction capital will be required before SOFAR can proceed.

In March 1983, the U.S. Bureau of Reclamation filed a lawsuit, asking the U.S. District Court to invalidate any water rights granted by the State Water Resources Control Board that give priority over federal water rights. USBR claims that it is not subject to State water law that gives a local area priority rights to local water, should it decide to build a water project.

Meanwhile, local USBR representatives have been cooperating with the El Dorado Irrigation District and the El Dorado County Water Agency to clear the way for the district to proceed while USBR and SWRCB argue their positions in court. A proposal by the district is being reviewed by the local USBR staff, who will send a recommendation to Washington, D.C., for review and approval.

Figure 66. SURFACE WATER PROJECTS–
SAN JOAQUIN HYDROLOGIC STUDY AREA

Figure 67. WATER SUPPLY AND USE SUMMARY SAN JOAQUIN HYDROLOGIC STUDY AREA 1980-2010



Thousands of acre-feet

NET WATER USE	1980	1990	2000	2010	CHANGE 1980-2010
IRRIGATION	5892	6050	6160	6370	480
URBAN	249	310	360	420	170
WILDLIFE AND RECREATION	74	80	80	80	10
ENERGY PRODUCTION	15	20	20	20	—
CONVEYANCE LOSSES	111	120	130	130	20
TOTAL	6341	6580	6750	7020	680
DEPENDABLE WATER SUPPLY					
LOCAL SURFACE WATER DEVELOPMENT	3055	3030	3020	3000	-60
IMPORTS BY LOCAL WATER AGENCIES	—	—	—	—	—
GROUND WATER	972	970	900	910	-60
CENTRAL VALLEY PROJECT	1838	2040	2230	2280	440
OTHER FEDERAL WATER DEVELOPMENT	55	55	55	55	0
WASTE WATER RECLAMATION	21	25	25	30	10
STATE WATER PROJECT	8	8	8	8	0
TOTAL	5949	6130	6240	6280	330
GROUND WATER OVERDRAFT	391	430	470	680	290
SWP SURPLUS WATER DELIVERY	—	—	—	—	—
SHORTAGE 1/	1	20	40	60	60
RESERVE SUPPLY 2/	191	320	220	230	

Totals for 1990, 2000, 2010, and CHANGE are rounded

1/ MOSTLY LOCAL

2/ MINOR LOCAL AMOUNTS AND CVP, 1980: ADDITIONAL CVP, FUTURE (NEW MELONES)

SAN JOAQUIN HYDROLOGIC STUDY AREA

Total annual net water use is projected to increase by about 680,000 acre-feet by 2010, including 480,000 acre-feet in agricultural use and about 170,000 acre-feet in urban use. Delivery of Central Valley Project reserve supply from New Melones and Folsom Reservoirs and the Sacramento-San Joaquin Delta would provide about 440,000 acre-feet of the required increase in supply. The remaining net use is expected to be supplied from increased ground water overdraft of about 290,000 acre-feet annually.

Ground Water Overdraft

Since the area will continue to rely on ground water as a source for irrigated agriculture, water agencies are attempting to alleviate the overdraft conditions through artificial recharge and conjunctive use programs. Immediate problems caused by overdrafting are localized land subsidence, water quality degradation near Stockton from salt-water intrusion, and higher pumping costs.

Sierra Foothills Region

Surface water systems in this region lack adequate storage to serve as dependable sources of water for irrigation and urban use. Furthermore, because of the geologic formations of this region, which are characterized by fractured rock, ground water is an unreliable source. As a result, water resources undergo wide seasonal and yearly fluctuations. This problem was evident during the 1976–77 drought, when many communities and rural users were forced to undergo severe water rationing.

Supplemental water supplies to alleviate some of the present shortage in Calaveras County would be provided by the proposed North Fork Stanislaus River Project. Calaveras County Water District (CCWD) is planning to construct a multipurpose project to develop energy and regulate water to supply the future needs of the county. The project would consist of several facilities upstream from New Melones Reservoir, including enlargement of Spicer Meadow Dam and Reservoir on Highland Creek and construction of three diversion dams, three tunnels, two power plants, and an afterbay. Approximately 192,000 acre-feet of storage and 205 megawatts of hydroelectric generating capacity would be provided by this project. The estimated first cost is between $300 and $350 million at 1982 prices.

Annual yield estimates range from 68,000 to 103,000 acre-feet. About 57,000 acre-feet of this yield is planned for Calaveras County, and the balance would be available for downstream power development to assist in financing the project. The Northern California Power Agency (NCPA) would participate in the development of the project by purchasing the power as agreed in a memorandum of understanding between CCWD and NCPA in 1977. A license from the Federal Energy Regulatory Commission (FERC) was issued to CCWD in January 1982. However, both the Pacific Gas and Electric Company and the Friends of the River have protested the issuance of the license. PGandE is protesting because the proposed project would directly or indirectly affect several of PGandE's power facilities in the portion of the Stanislaus River watershed in Calaveras County. Friends of the River's protest of the project involves environmental concerns. Construction of a New Spicer Meadow Dam and Reservoir would inundate Gabbot Meadow, an area that supports a large deer herd. The matter is now (1982) in the U.S. Court of Appeals in Washington, D.C.

The Cosumnes River Water and Power Authority

was formed in March 1981 by a joint powers agreement between the boards of supervisors of Amador and El Dorado Counties. (Sacramento and San Joaquin Counties joined the Water and Power Authority later.) Its purpose was to study the possibility of developing a water supply and power project on the Cosumnes River and its tributaries. Prior studies by the Cosumnes River Association showed that a project including Steely, Bakersford, and Cape Cod Dams, with a combined reservoir storage capacity of about 500,000 acre-feet and four power plants having a generating potential of about 217 million kilowatt-hours per year, was potentially feasible. Some 94,000 acre-feet of water per year could be developed by the project for water needs above the proposed Cape Cod Regulating Reservoir. The project would develop an additional 69,600 acre-feet for use downstream from Cape Cod Reservoir.

FERC preliminary applications have been made for several new hydroelectric power projects in the HSA. The East Bay Municipal Utility District has proposed the Upper Mokelumne River Hydroelectric Project, consisting of Middle Bar Dam, Railroad Flat Dam, Middle Fork Diversion Dam, and two power plants. The city and county of San Francisco and the Modesto Irrigation District have proposed the Clavey-Wards Ferry Project on the Tuolumne River and tributaries. PGandE has applied for a Kerckoff II project to further develop the head from Kerckoff Reservoir to Millerton Lake. The Upper San Joaquin Water and Power Authority has applied for a project on Granite and Jackass Creeks.

Folsom South Canal Service Area

The Folsom South Canal service area of the CVP, which includes portions of Sacramento and San Joaquin Counties in the Sacramento and San Joaquin HSAs, is one of the areas experiencing ground water overdraft. The problem is most evident near the city of Stockton, an area that presently depends on ground water as a major supply for irrigated agriculture and urban development. Water agencies are planning to eliminate ground water overdraft by importing surface water for conjunctive use with ground water. The alternative most often considered for additional surface water is the Auburn-Folsom South Unit of the CVP, which includes Auburn Dam and completion of the Folsom South Canal. The Delta and/or New Melones Reservoir have also been mentioned as possible sources. The Auburn-Folsom South Unit has been the subject of a major conflict. The State of California contends that USBR, the builder of the dam, must provide instream flows in the lower American River in accordance with SWRCB Decision 1400. USBR's position is that the additional water developed by Auburn Reservoir is not adequate to meet requirements in the Folsom South Canal service area and also the instream flows needed to meet the requirements of Decision 1400. An attempt was made to negotiate a memorandum of understanding between all parties to resolve the conflict, but discussions were discontinued in 1978.

Because of uncertainties surrounding reauthorization of Auburn Dam, the Department of Water Resources investigated other water management alternatives for satisfying the water needs of the Folsom South Canal service area. The Department's investigation indicates that, by completing the Folsom South Canal, (1) water needs of the Folsom South service area to 2000 can be met by use of firm yield from Folsom Lake and conjunctive use of non-firm yield and ground water, and (2) by using those measures and other alternatives, water needs beyond 2000 can be met without Auburn Dam. The investigation was predicated on meeting the minimum lower American River flows prescribed by Decision 1400 with relatively minor modifications. New studies by USBR indicate partial agreement with the Department's lower estimate of water needs in the service area. As noted earlier in this chapter, this CVP unit is being re-evaluated by USBR in connection with authorization by Congress.

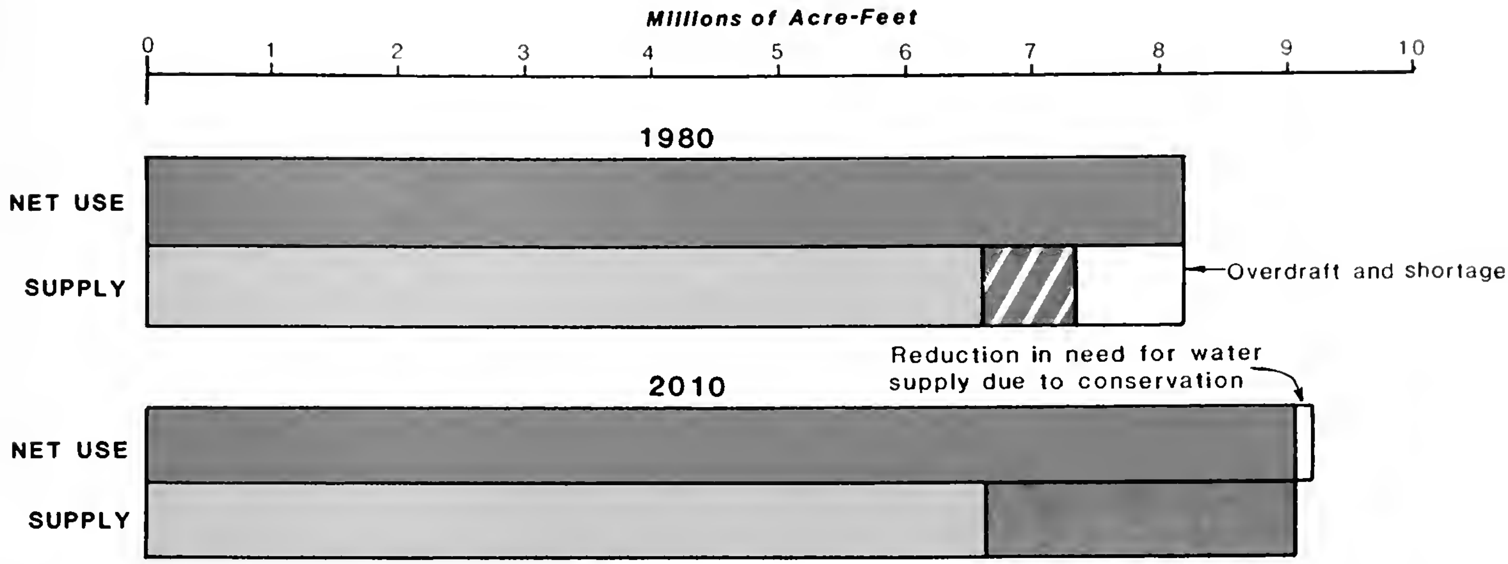
Delta Service Area

The main source of water in the Sacramento-San Joaquin Delta is the surface water in the channels, which is derived from unregulated streamflow, return flow from upstream uses, and releases from upstream storage reservoirs. The Delta channels also serve as a collection point and water transfer system for water drawn on by the two statewide water projects, the CVP and the SWP. To protect this water against salinity intrusion from San Francisco Bay, it is essential to maintain a sufficient outflow of fresh water.

Under State law, the Department and the U.S. Bureau of Reclamation are required to maintain water quality standards in the Delta channels as defined in SWRCB water right Decision 1485, and as it may be amended in the future. In addition, the Department has reached an agreement with the North Delta Water Agency and the East Contra Costa Irrigation District to maintain quality standards set by the contracts within their boundaries. The standards set forth in the contracts, or future standards set by SWRCB, whichever are higher, will prevail. Under the provisions of a draft Coordinated Operations Agreement, as yet unexecuted, both the CVP and the SWP would be committed to meet the single set of specified water quality and outflow standards for the Delta set forth in Decision 1485. In previous years, the USBR has agreed to meet the Decision 1485 standards voluntarily, except possibly in critically dry years. Water is released from upstream State and federal reservoirs—Oroville, Clair Engle, Shasta, and Folsom—to maintain quality and for other SWP and CVP purposes. The Department has attempted to negotiate agreements with other Delta water users but has not yet succeeded.

Figure 68. SURFACE WATER PROJECTS – TULARE LAKE HYDROLOGIC STUDY AREA

Figure 69. WATER SUPPLY AND USE SUMMARY
TULARE LAKE HYDROLOGIC STUDY AREA 1980-2010



Thousands of acre-feet

NET WATER USE	1980	1990	2000	2010	CHANGE 1980-2010
IRRIGATION	7781	7955	8185	8475	700
URBAN	236	280	310	350	110
WILDLIFE AND RECREATION	38	40	40	40	—
ENERGY PRODUCTION	10	25	40	40	30
CONVEYANCE LOSSES	123	125	125	125	—
TOTAL	8188	8425	8700	9030	840
DEPENDABLE WATER SUPPLY					
LOCAL SURFACE WATER DEVELOPMENT	2199	2199	2199	2199	0
IMPORTS BY LOCAL WATER AGENCIES	—	—	—	—	—
GROUND WATER	551	551	551	551	0
CENTRAL VALLEY PROJECT	2736	2780	2790	2790	50
OTHER FEDERAL WATER DEVELOPMENT	243	243	243	243	0
WASTE WATER RECLAMATION	67	80	90	100	30
STATE WATER PROJECT	795	730	720	720	-70
TOTAL	6591	6580	6590	6600	10
GROUND WATER OVERDRAFT	856	1190	1450	1770	910
SWP SURPLUS WATER DELIVERY 1/	741	—	—	—	-740
SHORTAGE 2/	0	655	660	660	660
RESERVE SUPPLY 3/	56	10	0	0	

Totals for 1990, 2000, 2010, and CHANGE are rounded

1/ Value for 1980 reflects delivery of SWP surplus water supplies that were used in lieu of pumping ground water and for direct recharge. (Average delivery for 1979-1981 was 741,000 acre-feet). Surplus water availability will be reduced in the future to meet increasing requirements and is expected to be available only in wet years until substantial additions to dependable supplies are available for the SWP. Future overdraft could be reduced from the amount shown by the extent that SWP surplus water deliveries can be made available (but see note 2).

2/ SWP, based on Figure 48 About 90 percent of this amount could be met from ground water, adding to the projected overdraft.

3/ CVP


INTERNATIONAL

TULARE LAKE HYDROLOGIC STUDY AREA

Total annual net water use in the Tulare Lake HSA is projected to increase about 840,000 acre-feet by 2010, including 700,000 acre-feet of agricultural use and 110,000 acre-feet of urban use. The additional needs are expected to be met by a small increase in CVP supplies, additional waste water reuse, and a substantial increase in ground water overdraft.

Ground Water Overdraft

The immense ground water overdraft in the Tulare Lake HSA is one of the most significiant unresolved water resource problems in California. The present rate of overdraft is calculated to be about 860,000 acre-feet per year. The importation of SWP water and the availability of 741,000 acre-feet of surplus supplies (1979–1981 average) have reduced average ground water overdraft from about 1,300,000 acre-feet in 1972 to 860,000 acre-feet in 1980. This has been achieved despite an increase in irrigated crop acreage of about 300,000 acres.

SWP surplus supplies will diminish as the requirements for water begin to exceed available supplies. Assuming that, by 2010, the SWP is augmented by only the projects shown in Figure 48, shortages in dependable water supplies would reach 660,000 acre-feet per year. About 90 percent of this shortage can be made up from ground water, which would result in a total overdraft in 2010 as high as 2,400,000 acre-feet per year. However, in wetter-than-normal years, some surplus surface supplies will continue to be available for ground water recharge, to the extent the California Aqueduct has capacity available to deliver the water. Also, if additions to SWP yield can be provided before 2010, ground water overdraft may not reach the level indicated.

The proposed Mid-Valley Canal addition to the Central Valley Project, discussed earlier in this chapter, would also reduce the rate of ground water overdrafting by providing replacement water to irrigated areas. Preliminary studies indicate an average of about 450,000 acre-feet per year would be provided to the Tulare Lake HSA. (A north branch would provide about 160,000 acre-feet per year to the San Joaquin HSA.)

Recently, large increases in electrical energy costs have given water agencies added incentive to intensify ground water recharge efforts in an attempt to reduce pumping lifts. The availability of SWP surplus supplies and the completion of the Cross Valley Canal in 1975 have enabled Kern County Water Agency to implement a large-scale program aimed at mitigating overdraft. This program is over and above all other recharge programs and other projects using surface water in lieu of pumping in the area.

Numerous public and private water agencies are engaged in the acquisition, distribution, and sale of surface water to growers in the Tulare Lake HSA. Since most of the agencies overlie usable ground water and use ground water conjunctively with surface water, some of their operational practices such as artificial recharge and use of "nonfirm" surface supplies in lieu of ground water can be viewed as elements of a ground water management program. The agencies do not, however, have the power to control ground water extractions. Such authority is a requisite to comprehensive ground water management.

Dinkey Creek Project

The large increases in the value of electrical energy have made some projects that were either infeasible, or only marginally feasible, financially more attractive. As a result, the Kings River Conservation District is investigating additional development of the upper Kings River and its tributaries for power, flood control, and water conservation. In addition to adding power to Pine Flat Dam (now under construction), the Dinkey Creek Project on Dinkey Creek, a tributary to the North Fork of the Kern River, was found to be economically justified, and the Kings

In the absence of a drainage export facility, evaporation ponds are used as salt sinks to dispose of drainage water too salty for reuse.

River Conservation District has applied to the Federal Energy Regulatory Commission for a license. Although the project would be operated primarily to maximize power benefits, the 90,000-acre-foot reservoir would also develop about 10,000 acre-feet annually of new water for the Kings River service area.

Salt Management

The valley floor of the Tulare Lake HSA is essentially a closed basin, and most salts brought into the basin with water supplies, fertilizer, and soil amendments are not removed. These conditions have been studied extensively. The most recent, the San Joaquin Valley Interagency Drainage Program, was conducted jointly by the Department, USBR, and SWRCB, and culminated in a report, *Agricultural Drainage and Salt Management in the San Joaquin Valley*,[2] June 1979. The report defines the problem, describes alternative solutions, and recommends a plan for solution of the problem—export of brackish water from the Tulare Lake HSA. The location of the proposed valley drain is shown on Figure 70.

There is very little willingness at this time among the beneficiaries of the drain to move ahead with the recommended plan. At this time, only a few farmers are threatened by a high water table because drain water is unable to percolate at a sufficient rate through underlying clay strata. The problem is of no immediate or near future concern for the larger number of farmers who may eventually be affected and who would be needed to spread the cost in financing a master drain. As an interim solution, local interests are constructing facilities to convey drainage water to large evaporation ponds located on poor-quality land, where the salts are concentrated.

[2] *Agricultural Drainage and Salt Management in the San Joaquin Valley: Final Report Including Recommended Plan and First-Stage Environmental Impact Report.* San Joaquin Valley Interagency Drainage Program; U.S Bureau of Reclamation, California Department of Water Resources, the California State Water Resources Control Board; with Appendixes to Final Report, June 1979 (reprinted November 1979).

Figure 70. PROPOSED VALLEY DRAIN

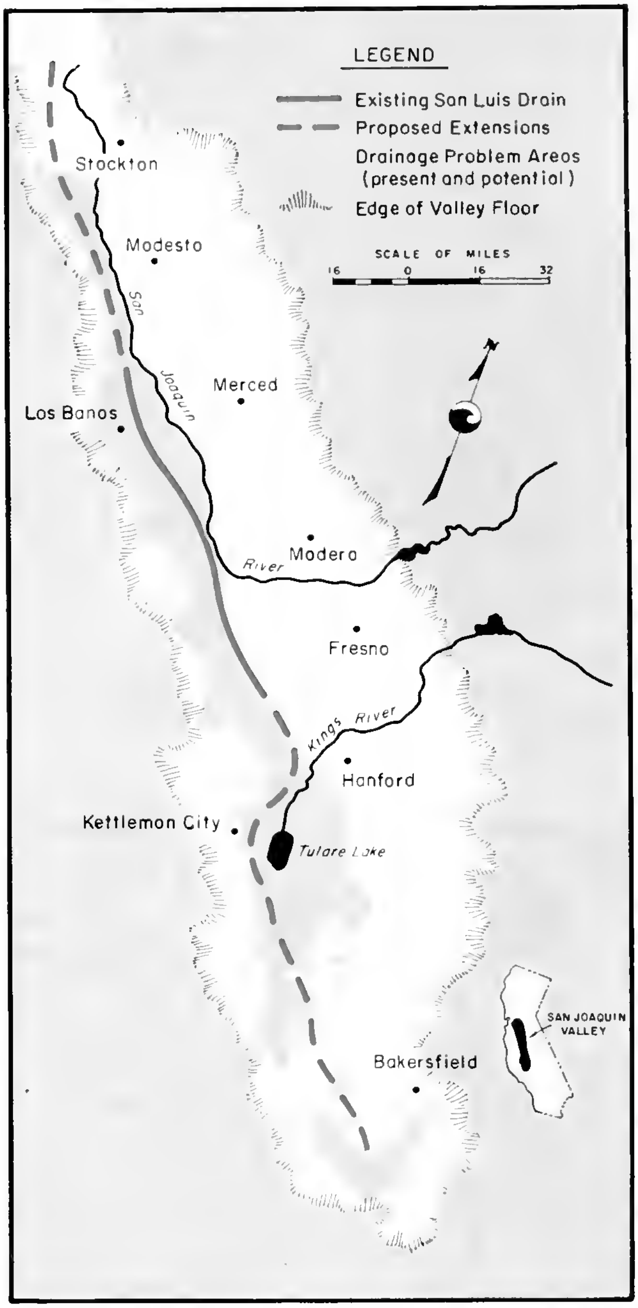
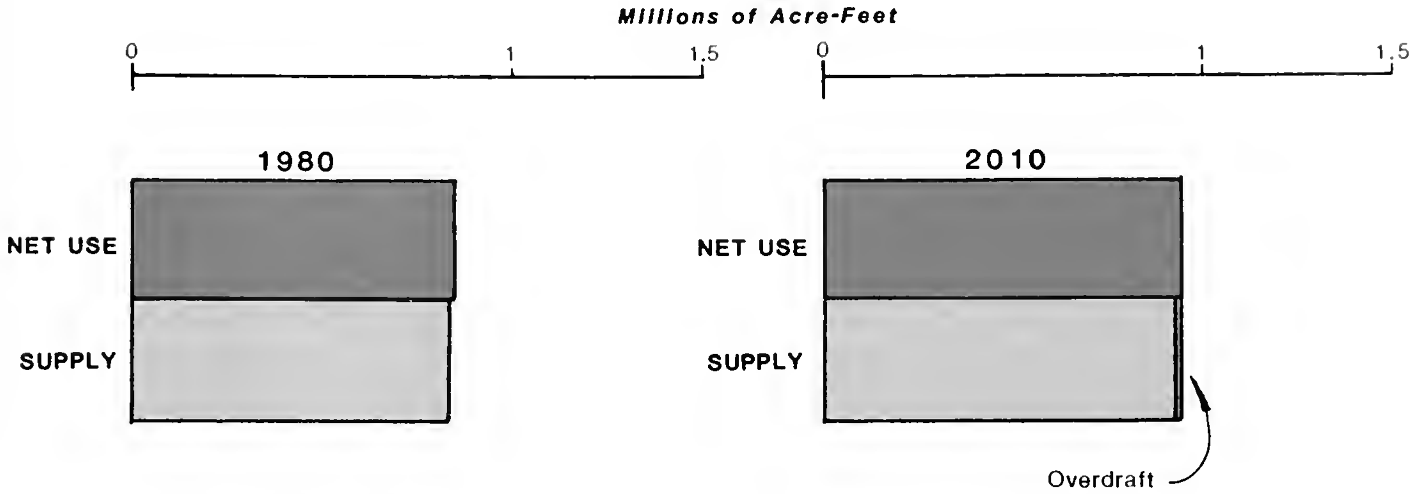


Figure 71. SURFACE WATER PROJECTS - NORTH LAHONTAN HYDROLOGIC STUDY AREA

Figure 72. WATER SUPPLY AND USE SUMMARY NORTH LAHONTAN HYDROLOGIC STUDY AREA 1980-2010



Thousands of acre-feet

NET WATER USE	1980	1990	2000	2010	CHANGE 1980-2010
IRRIGATION	387	410	410	420	30
URBAN	23	30	35	40	20
WILDLIFE AND RECREATION	11	10	10	10	0
ENERGY PRODUCTION	—	—	—	—	—
CONVEYANCE LOSSES	—	—	—	—	—
TOTAL	421	450	455	470	50
DEPENDABLE WATER SUPPLY					
LOCAL SURFACE WATER DEVELOPMENT	312	310	310	320	10
IMPORTS BY LOCAL WATER AGENCIES	11	11	11	11	0
GROUND WATER	88	110	120	120	30
CENTRAL VALLEY PROJECT	—	—	—	—	—
OTHER FEDERAL WATER DEVELOPMENT	—	—	—	—	—
WASTE WATER RECLAMATION	5	10	10	10	—
STATE WATER PROJECT	—	—	—	—	—
TOTAL	416	440	450	460	40
GROUND WATER OVERDRAFT	5	10	5	10	10
SWP SURPLUS WATER DELIVERY	—	—	—	—	—
SHORTAGE	—	—	—	—	—
RESERVE SUPPLY 1/	17	20	20	20	

Totals for 1990, 2000, 2010, and CHANGE are round.

1/ MOSTLY LOCAL PROJECTS, PLUS SOME FROM STAMPEDE RESERVOIR.

NORTH LAHONTAN HYDROLOGIC STUDY AREA

In the North Lahontan HSA, annual net water use in 2010 is projected to be about 50,000 acre-feet greater than it was in 1980. The principal increases will be about 30,000 acre-feet for irrigated agriculture and about 20,000 acre-feet for urban uses.

Ground water will provide the principal source of water, with annual net use projected to increase by about 30,000 acre-feet by 2010. Expanded development of local surface water will supply the remainder.

Nearly all the growth in agricultural water use is expected to take place in Modoc and Lassen Counties. Little is known, however, about the potential ground water yield in this part of the HSA and the recent rapid increase in ground water pumping is causing concern. An example of these concerns and other water management-related issues important to this HSA follows.

Surprise Valley Ground Water

Ground water pumping for the production of alfalfa by sprinkler irrigation has doubled since 1960. Some areas of Surprise Valley, particularly around Cedarville, may already be in overdraft. Wells located nearer the mountains on the west side of the valley nearly cease flowing in late July and August, but, according to well measurement data, they recharge fully by the following spring. Increased pumping higher on the alluvial fan has reduced the water supplies reaching some of the meadow pastures along the margins of the alkali lakes in this area; this pumping creates space for recharge from local creeks that formerly irrigated the meadows. The Department of Water Resources is presently studying Surprise Valley to evaluate the probable impact of increased pumping and to examine means of increasing ground water recharge.

California-Nevada Interstate Compact

California and Nevada have agreed to allocate between them the water supply of Lake Tahoe and the Truckee, Carson, and Walker Rivers. The California-Nevada Interstate Compact was approved by the California Legislature in 1970 and the Nevada Legislature in 1971. However, the compact will not go into

effect until it is approved by Congress. That approval has been held up by federal agencies that believe (1) the United States should not be bound by terms of the compact, and (2) the compact would prejudice efforts to increase inflow to Pyramid Lake to preserve the fishery.

The Tahoe Regional Planning Agency (TRPA) is responsible for controlling land use in the Lake Tahoe Basin to protect the lake from quality degradation. The State Water Resources Control Board has made detailed studies of current and potential future water use in the basin under the limitations imposed by TRPA and the interstate water compact. Similar studies have not been made for the Truckee, Carson, and Walker River Basins; therefore, the projections in this report for the three river basins are not as reliable as those for the Tahoe Basin.

The Pyramid Lake Paiute Indian tribe has sued the State of California, and others, to secure additional water to maintain Pyramid Lake and provide adequate flows for fish spawning in the Lower Truckee River (between Derby Dam and Pyramid Lake). USBR has declined to contract for the sale of water from Stampede Reservoir on Little Truckee River until this matter is resolved. In the interim, the reservoir is being operated for fishery enhancement. A 1982 decision in *Carson-Truckee Water Conservancy District, et al.* v. *Kleppe, et al.* sets a higher priority for fishery preservation than for municipal uses in the operation of Stampede Reservoir. Thus, the availability of water from the Truckee River will depend on the outcome of current litigation.

In the Carson and Walker River Basins, most of the irrigation water requirements are met by direct diversion from streams. Surplus water is usually present during the spring snowmelt period, but streamflows are low during most of the irrigation season. However, with a minor exception, storage projects studied to date have not been economical. The compact and the court decree, which is presently on appeal, would give Alpine County water users the right to store 2,000 acre-feet each year adverse to the federal Lahontan Reservoir downstream in Nevada.

Figure 73. SURFACE WATER PROJECTS - SOUTH LAHONTAN HYDROLOGIC STUDY AREA

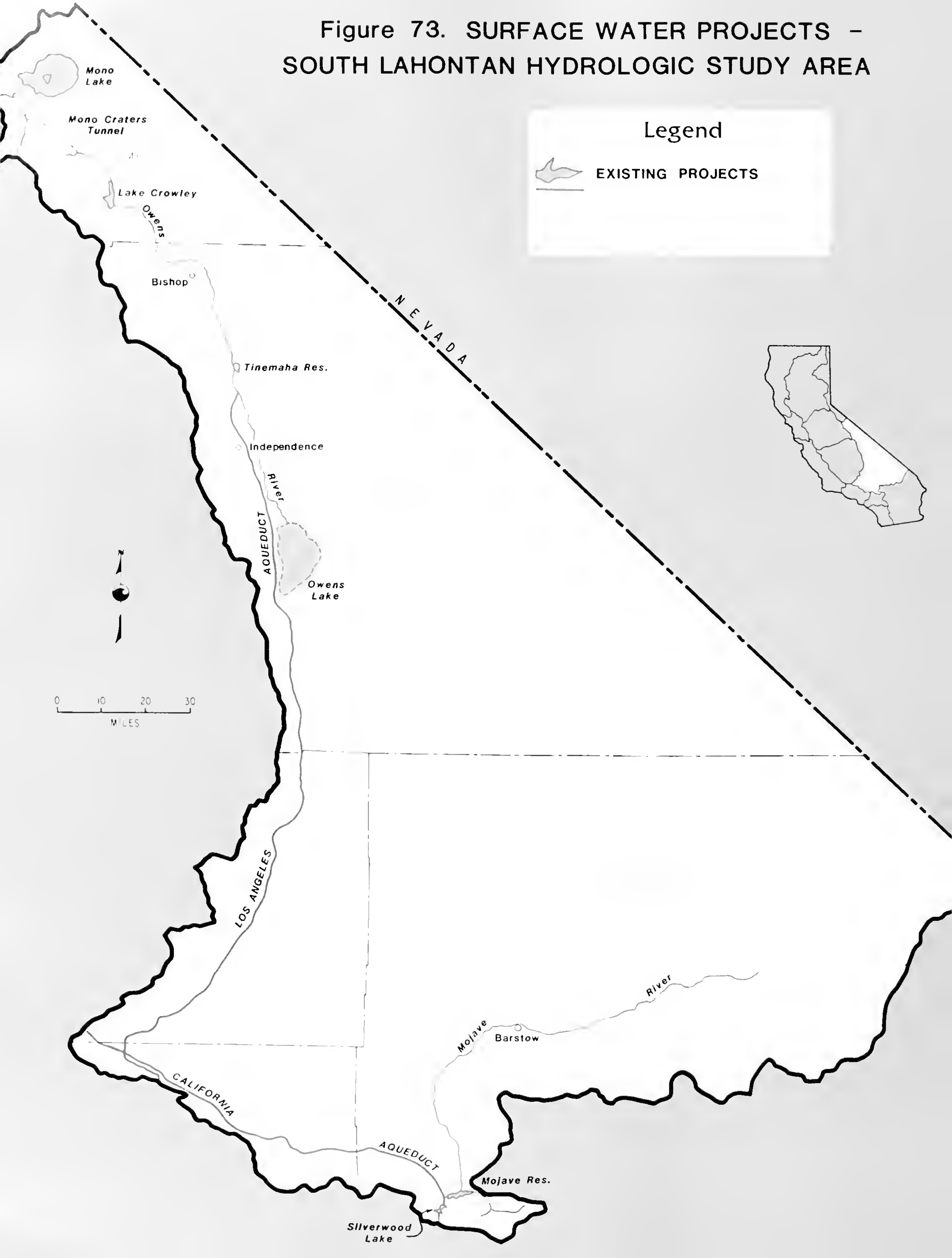
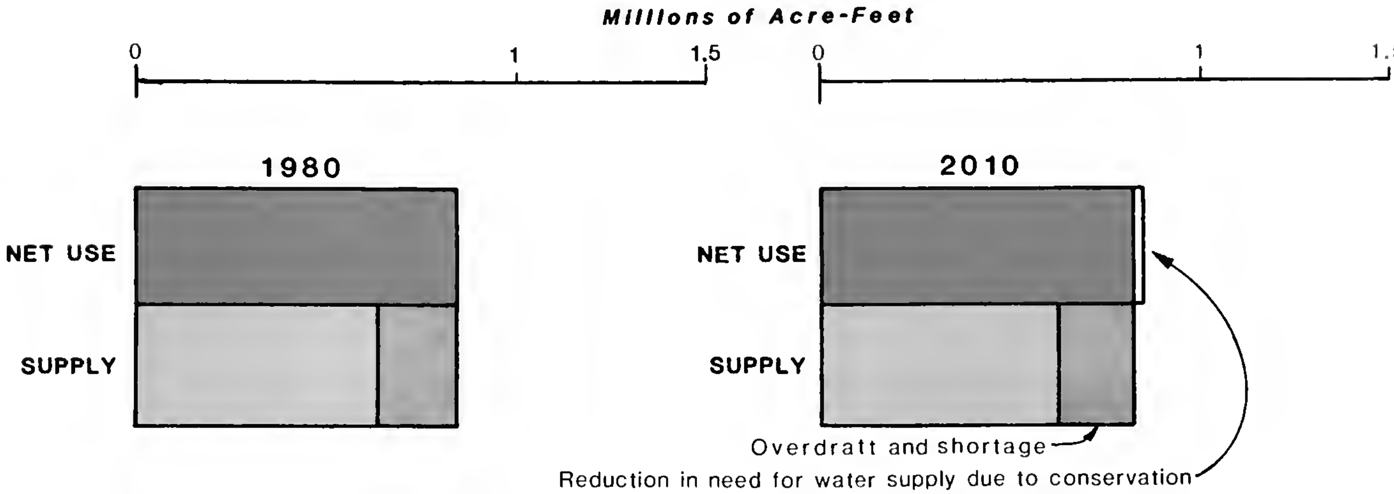


Figure 74. WATER SUPPLY AND USE SUMMARY SOUTH LAHONTAN HYDROLOGIC STUDY AREA 1980-2010



Thousands of acre-feet

NET WATER USE	1980	1990	2000	2010	CHANGE 1980-2010
IRRIGATION	338	300	270	230	-110
URBAN	60	80	110	120	60
WILDLIFE AND RECREATION	12	25	25	30	20
ENERGY PRODUCTION	2	5	15	25	20
CONVEYANCE LOSSES	7	5	5	5	0
TOTAL	419	415	425	410	-10
DEPENDABLE WATER SUPPLY					
LOCAL SURFACE WATER DEVELOPMENT	44	45	45	45	0
IMPORTS BY LOCAL WATER AGENCIES	—	—	—	—	—
GROUND WATER	178	180	170	130	-50
CENTRAL VALLEY PROJECT	—	—	—	—	—
OTHER FEDERAL WATER DEVELOPMENT	—	—	—	—	—
WASTE WATER RECLAMATION	9	10	15	15	10
STATE WATER PROJECT	85	110	115	120	30
TOTAL	316	355	355	310	-10
GROUND WATER OVERDRAFT	103	40	50	70	-30
SWP SURPLUS WATER DELIVERY	—	—	—	—	—
SHORTAGE 1/	—	20	20	30	30
RESERVE SUPPLY 2/	33	0	15	55	

Totals for 1990, 2000, 2010, and CHANGE are rounded.

1/ SWP (MOJAVE WATER AGENCY AND CRESTLINE LAKE ARROWHEAD WATER AGENCY

2/ SWP, 1980: SWP ENTITLEMENT WATER USED FOR GROUND WATER RECHARGE IN ANTELOPE VALLEY, FUTURE.

SOUTH LAHONTAN HYDROLOGIC STUDY AREA

Total annual net water use is expected to decline by about 10,000 acre-feet between 1980 and 2010. Agricultural net water use is expected to drop by about 110,000 acre-feet, reflecting a decrease of more than 30 percent in irrigated alfalfa and pasture acreage as ground water availability and costs become major problems in the area. However, urban net water use is expected to double, reaching about 120,000 acre-feet. Water for power plant cooling will add about 20,000 acre-feet to net use by 2010.

The large reduction in irrigated acreage projected by 2010 is expected to reduce ground water net use by about 80,000 acre-feet per year. Ground water overdraft would decrease by about 30,000 acre-feet per year. Much of the increase in urban net water use is expected to be met by a 30,000-acre-foot increase in SWP deliveries.

The water issues in the South Lahontan HSA involve: (1) exportation of water from the Owens-Mono area, and (2) local ground water quality and quantity problems.

Exportation of Water

The Los Angeles Department of Water and Power (LADWP) diverts both surface and ground water from the Owens Valley and surface water from the Mono Basin, totaling 483,000 acre-feet per year. In recent years, after deduction of conveyance losses, LADWP's supply averaged about 467,000 acre-feet, with an average of 100,000 acre-feet annually from the Mono Basin.

Since the commencement of LADWP's surface diversion project in Mono Basin in 1941, the lake's surface elevation has dropped more than 40 feet. However, lake levels recovered in 1982 and 1983 because of above-normal runoff and reduced diversions by LADWP.

In February 1983, the California Supreme Court issued its decision in the Mono Lake Litigation, *National Audubon Society* v. *Superior Court*. The Supreme Court held that water rights licenses issued to the city of Los Angeles to divert water tributary to Mono Lake are subject to the public trust doctrine. Under this doctrine, the State retains continuing supervision over the taking and use of water. The holder of a license issued by the State has no vested right to the use of water in a manner harmful to the trust. The public trust doctrine protects navigable waters from harm caused by diversion of nonnavigable tributaries.

The court also held that there is no duty to exhaust administrative remedies before the State Water Resources Control Board; rather, the courts and SWRCB have concurrent jurisdiction to consider whether the city's diversions violate the public trust.

H.R. 1341 (Richard Lehman, California), a bill that would establish a Mono Basin National Forest Scenic Area, is now being considered by Congress. If passed, the bill would provide land-use guidelines to preserve the scenic qualities of federally-owned property in the Mono Basin. The Secretary of Agriculture would manage the area in a manner consistent with the protection of California water rights, and this management would not affect or impair existing water appropriations and operations taking place in the Mono Basin.

In Owens Valley, residents have objected to ground water pumping by LADWP, contending that the extractions will severely lower ground water levels and adversely affect native plant and animal life. They also claim that health problems will develop as dust storms become more frequent. Pending resolution of this dispute, a court order has been issued that restricts pumping to a maximum rate of 149.5 cubic feet per second. This reduces the quantity of ground water available for delivery by the Los Angeles Aqueduct.

Both legal and legislative actions have been taken by opponents of LADWP's programs. Lawsuits have been filed by opponents (the Sierra Club, the Audubon Society, Inyo County, and the Great Basin Unified Air Pollution Control District) to seek either an end to or curtailment of the diversions by LADWP. In 1980, Inyo County voters passed a ballot measure to manage ground water extractions in the valley. That ordinance, which would have given the county the authority to limit pumping by LADWP, was ruled unconstitutional by the Superior Court in San Bernardino County.

Local Ground Water Use

Greater urban and agricultural water use has caused ground water levels to decline in Antelope Valley, Fremont Valley, and Indian Wells Valley. Agricultural net water use is projected to decrease from 338,000 acre-feet in 1980 to 230,000 acre-feet in 2010, primarily because the income from crops commonly grown here appears insufficient to pay the increased cost of ground water pumping.

Because of concern over recent and projected population growth and declining water levels in the Indian Wells area, the major water users and the U.S. Geological Survey are evaluating ground water recharge, the change in water levels, and the discharge from Indian Wells Valley. However, the projected economic base does not appear sufficient to support importation of needed water supplies.

In the Mojave River area, levels of nitrate, fluoride, and other mineral constituents in the ground water supplies have increased. Some basins in the area must continue to rely on ground water, despite declining water levels, until the local distribution system for State Water Project water is built.

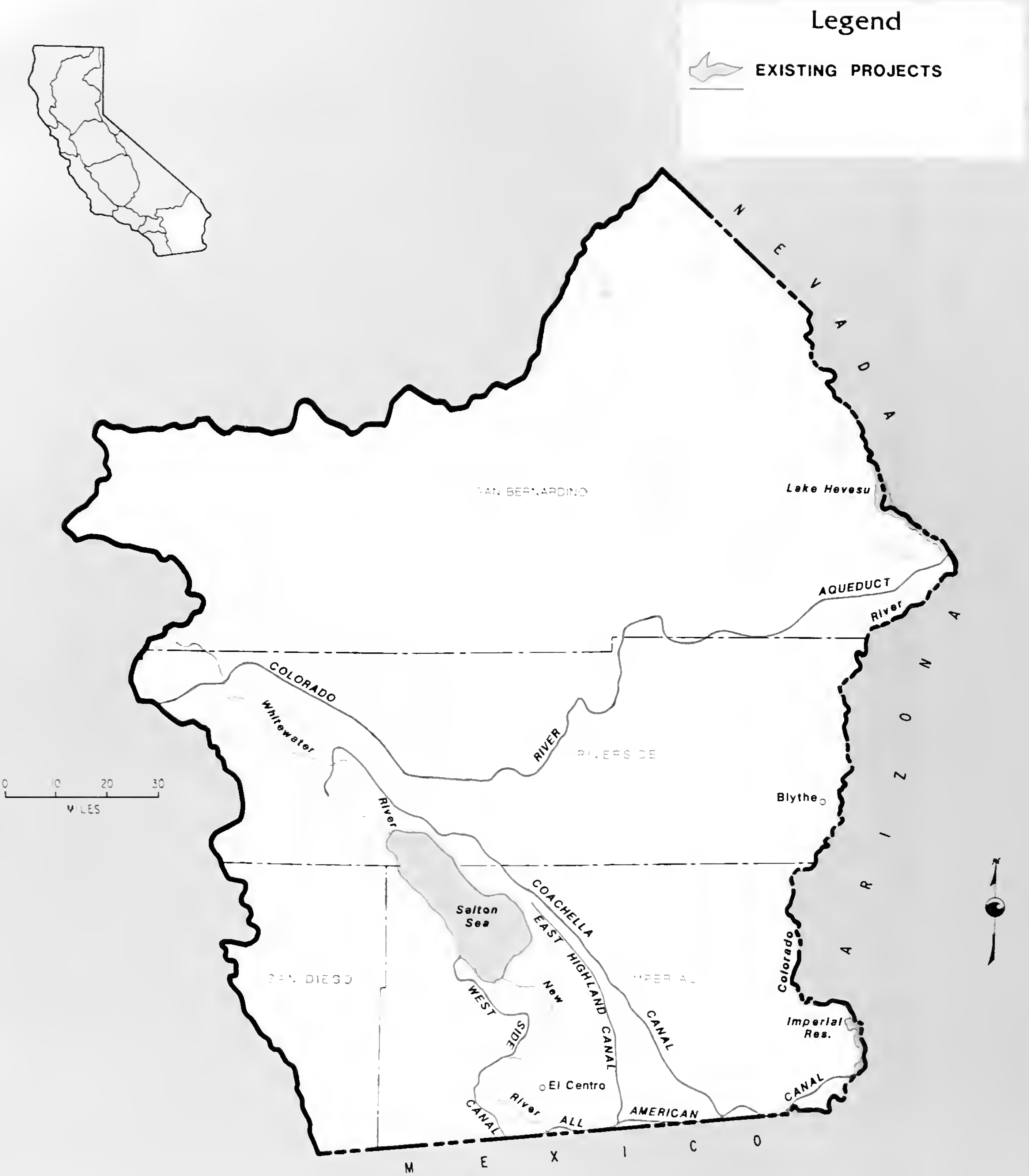
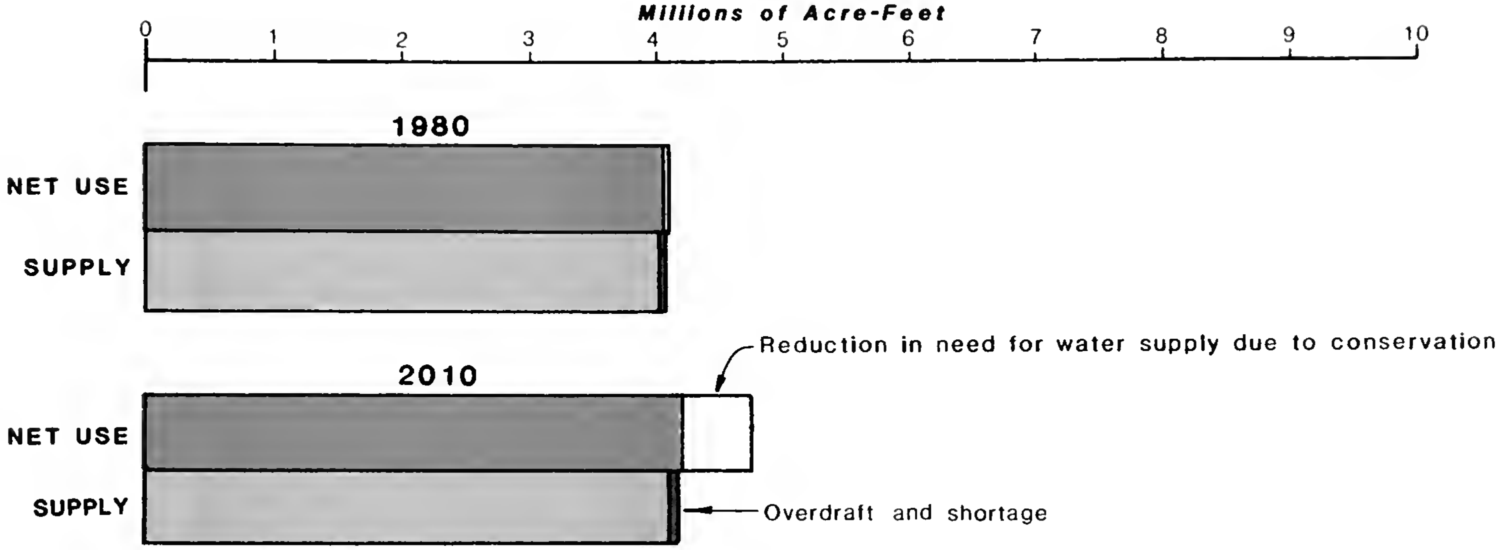


Figure 75. SURFACE WATER PROJECTS - COLORADO RIVER HYDROLOGIC STUDY AREA

Figure 76. WATER SUPPLY AND USE SUMMARY COLORADO RIVER HYDROLOGIC STUDY AREA 1980-2010



PROJECTED USE OF WATER SUPPLIES 1980-2010

Thousands of acre-feet

NET WATER USE	1980	1990	2000	2010	CHANGE 1980-2010
IRRIGATION	3434	3560	3700	3680	240
URBAN	102	130	170	200	100
WILDLIFE AND RECREATION	20	20	20	20	0
ENERGY PRODUCTION	3	20	30	45	40
CONVEYANCE LOSSES	543	360	280	280	-260
TOTAL	4102	4090	4200	4225	120
DEPENDABLE WATER SUPPLY					
LOCAL SURFACE WATER DEVELOPMENT	4	4	4	4	0
IMPORTS BY LOCAL WATER AGENCIES	—	—	—	—	—
GROUND WATER	68	70	70	70	0
CENTRAL VALLEY PROJECT	—	—	—	—	—
OTHER FEDERAL WATER DEVELOPMENT	3970	3920	3990	3990	20
WASTE WATER RECLAMATION	3	20	30	40	40
STATE WATER PROJECT	30	40	40	40	10
TOTAL	4075	4050	4130	4140	70
GROUND WATER OVERDRAFT	27	10	30	50	20
SWP SURPLUS WATER DELIVERY	—	—	—	—	—
SHORTAGE [1]	—	30	40	35	30
RESERVE SUPPLY [2]	4	0	0	0	

Totals for 1990, 2000, 2010, and CHANGE are rounded.

1/ SWP

2/ SWP

COLORADO RIVER HYDROLOGIC STUDY AREA

Total annual net water use between 1980 and 2010 is projected to increase by only about 120,000 acre-feet, most of which is increased urban use. This suggests little change in agricultural water use; however, this is not the case. By use of water saved by intensified conservation measures, irrigated acreage was projected to increase significantly. This would result in an increase in evapotranspiration of applied water of more than 400,000 acre-feet by 2010, with essentially the same water supply as is currently used, but with considerably reduced losses to the Salton Sea and to saline ground water. There are supplemental water needs in other parts of the HSA that can be met by a combination of State Water Project deliveries and ground water overdraft. The Colorado River Indian tribes were projected to use their full entitlement of 55,000 acre-feet by 2000.

The following are the more significant water issues in this HSA.

The Salton Sea

Concern about the rising level of the Salton Sea has been a major factor in recent water conservation efforts in this HSA. The water level in the sea is rising and inundating surrounding land. The Salton Sea is a natural sump and is maintained mainly by return irrigation flows from the Imperial and Coachella Valleys, augmented by flows from occasional tropical storms. It is recognized as a valuable fishery and wildlife refuge. Reduction of return flows, either through conservation or as a result of their use in developing geothermal resources in the area, could cause the level of the sea to decline, increasing the concentration of salts in the water. This would impair fish life and isolate shoreline development.

Imperial Valley Water Conservation

Over the past several years, efforts have increased to improve the efficiencies of distribution and use of irrigation water in the Colorado River HSA. The lining of the Coachella Canal in 1980 is estimated to save 110,000 acre-feet of water per year that had previously been lost to seepage. Similarly, the lining of distribution canals in Imperial Valley now saves an estimated 130,000 acre-feet per year.

Continuing concern for better water management in Imperial Valley has led the Imperial Irrigation District (IID) to implement water conservation programs directed toward reducing excess water use.

The findings of an investigation conducted by the Department of Water Resources at the request of an IID farmer were published in December 1981 in the Department's report, *Investigation under California Water Code Section 275 of Use of Water by Imperial Irrigation District*. The study concluded that, based on average conditions prevailing from 1975 to 1979, an estimated 438,000 acre-feet of water could be saved annually in the Imperial Valley through various improvements in distribution systems and irrigation management. Identified measures included lining of portions of the All-American Canal, lining of additional segments of the district's laterals, construction of more regulatory reservoirs, elimination of canal spills, expanded use of seepage recovery systems, and implementation of irrigation management programs to reduce excess irrigation runoff. Some of these actions, such as lining the All-American Canal, may not be cost-effective for the district. Improvements already being implemented are being funded through higher water rates to customers and penalty assessments to farmers found to be wasting water.

The salvaged water reportedly could be used in a number of ways. First, the water could be put to use on lands within the IID now being irrigated with Colorado River water. The four California agricultural agencies with rights to Colorado River water are presently using about 80,000 acre-feet more than the 3.85 million acre-feet per year allocated under the Seven Party Agreement. When the Central Arizona Project becomes operational around 1985, these agencies—the Palo Verde Irrigation District, the Yuma Project, the IID, and the Coachella Valley Water District—must reduce consumptive use to the level of their firm entitlement. As a result, some of the water salvaged by lining the Coachella Canal and from improved conservation practices will probably be used to sustain existing agriculture.

Second, not all the irrigable lands within the IID are presently being irrigated. Landowners in these areas would probably farm more land, if more water becomes available on a firm basis. The water saved could, therefore, be used for this purpose.

Third, agricultural water use varies widely from year to year in response to climatic conditions, type of crops planted, and other factors. Thus, the need for water to accommodate those variations must be recognized.

Fourth, if the conserved water could be made available to coastal Southern California, that area could reduce its purchase of SWP water, temporarily reducing demands on the SWP system. However, there are legal and institutional issues involved in such a transfer.

In this report, it was estimated that 394,000 acre-feet of water could be salvaged between 1980 and 2010 and would be put to use for irrigation of additional crops in IID.

CHAPTER VI

OPTIONS FOR THE FUTURE

The purpose of this chapter is to discuss some of the options which should be examined by water managers as they address means of meeting water needs. Chapter V discussed the water supply situation as it relates to the increased demands being placed on the developed resource. It was shown that, statewide, net water use is expected to total 37.3 million acre-feet by 2010, while the developed dependable supply is about 33 million acre-feet. In the State Water Project service areas, requirements are estimated to be 1.5 million acre-feet greater than the yield of existing and authorized facilities. This is the major identified water management issue.

In the first section of this chapter, net water use-water supply relationships are reviewed for each major region of the State. This is followed by a discussion of the potential for developing additional water supplies, water supply savings gained from more intensive water conservation (beyond those presented in Chapter IV), and other management options available to water managers. The chapter concludes with a view of government agency roles.

Constraints on Water Management

The choice of water management options will be constrained or influenced by a number of policy decisions. Water quality decisions, for example, may constitute an additional demand on the system. The Delta Decision (Decision 1485) requires the maintenance of minimum water quality standards in the Sacramento-San Joaquin Delta. Under this decision, slightly more than 5.0 million acre-feet annually, including more than 1.0 million acre-feet of developed supply, is needed as Delta outflow to meet these standards. Any revision of these standards, therefore, would affect the supply capabilities of the State Water Project and the federal Central Valley Project.

Other potentially serious water quality problems include areas with high brackish water tables, particularly the San Joaquin Valley, where about 400,000 acres of irrigated land are now increasingly and seriously threatened. Ultimately, more than 1.0 million acres could be similarly threatened. Productive capacity of these lands can be maintained only by installation of adequate soil drainage and saline water disposal systems.

Decisions regarding water supply allocations for instream uses, including wild and scenic river designations, have a direct bearing on the amount of water available for development and on the operation and yield of existing and proposed projects. Estimates and projections in this report are premised on satisfaction of instream flows agreed upon through negotiations and water rights procedures.[1] However, as more knowledge is gained of instream uses and related needs, further actions and decisions could affect the water supply options discussed in this chapter.

Finally, the water management options discussed have not been studied sufficiently to assess engineering, environmental, economic, or financial feasibility. Although it is generally recognized in this report that water costs will increase significantly in coming years, benefits are expected to increase as well. Moreover, actions by the federal government to revise cost-sharing provisions associated with water projects would shift a significant financial burden to the states or other non-federal entities and may affect project feasibility.

The Resource Supply Outlook

Consideration of water resources in California involves two separate concepts—the *total* resource and the *developable* resource. The developable resource is that portion of the resource that can reasonably be converted to a usable supply. The two are markedly different. This section identifies the total resource, by major region, and discusses the ever-widening gap between the total, or physical, resource and the remaining developable resource, as limited by economic, political, and social constraints.

The Total Surface Water Resource

California's long-term natural (unimpaired) runoff was evaluated intensively during the Statewide Water Resources Investigation, authorized in 1947, the results of which were published in *Water Resources in California* (Bulletin 1, 1951). The total mean annual

[1] See *Inventory of Instream Flow Requirements Related to Stream Diversions*. Bulletin 216, Department of Water Resources, December 1982.

natural runoff of all California streams for the 50-year period from 1897 through 1947 was estimated to be 70.8 million acre-feet, excluding imports from the Colorado River and inflow from Oregon.

California's long-standing claim of 5.4 million acre-feet from the Colorado River was reduced to 4.4 million acre-feet by a decision of the U.S. Supreme Court in 1964, which awarded an additional 1.0 million acre-feet to Arizona for the Central Arizona Project. Decisions are pending on further reductions to satisfy Indian water rights. Such actions would be at the expense of The Metropolitan Water District of Southern California (MWD). For this discussion, the Colorado River supply available to California is assumed to be 4.4 million acre-feet per year. This brings the total resource to 78.5 million acre-feet. (See Figure 47 in Chapter V.)

The Present Water Supply Situation

Because of an aggressive water development program that covered several decades and ended in the early 1970s with completion of the California Aqueduct and terminal State Water Project reservoirs, California's present water needs are generally being satisfied by dependable water supplies. There are, however, two notable exceptions. The first is communities and agricultural areas dependent on local streams, with small or no storage reservoirs. They are often short of water toward the end of summer, and are critically short during drought years. The other important exception is areas that overdraft ground water basins year after year. The most outstanding example of this situation is the San Joaquin Valley, where the persistent annual overdraft is about 1.2 million acre-feet. While water uses are presently being satisfied by overdraft, it is not a dependable supply. Eventually, economic forces or other restraints will compel pumpers to cut back in some areas, causing changes in irrigated agriculture, unless provisions are made for new imported supplies.

The Future Water Supply Situation

Several events, some of them recent, have cast uncertainty over the ability to satisfy future water needs. In some instances, opposition to proposed projects has resulted from confusion arising from a combination of economic, political, environmental, and emotional concerns.

Any program to increase developed supply will be affected by a variety of constraints that have contributed to the delay or rejection of proposed projects.

Basic Water Supply-Net Water Use Assumptions. Assumptions regarding the origin and magnitude of water supplies available to satisfy future net water use are summarized in this section. As described earlier in this report, it was assumed that additional surface water supplies developed by 2010 would be obtained from Central Valley sources.

- The South Coastal region derives its water supply from underground storage, local surface storage, and imports from the Colorado River, the Mono Lake-Owens Valley area, and the State Water Project. Local water supplies are fully developed, including ground water. It is assumed that imported water supplies from Mono Lake basin, Owens Valley, and the Colorado River entitlements will remain the same. Additional water supplies must come from the Central Valley through the State Water Project. However, there is potential for reducing water use in the Imperial Valley that could make additional supplies available. (See Chapter V for a detailed discussion.)
- The Central Coast HSA will meet its future water needs largely from increased local development and from the San Felipe Division of the federal Central Valley Project, which will serve water to San Benito County and south Santa Clara Valley. In addition to increased local water supplies, supplemental supplies for Santa Barbara and San Luis Obispo Counties would have to come from the State Water Project through the proposed coastal aqueduct.
- The San Francisco Bay HSA will satisfy its future water needs by increased imports from Central Valley sources. These imports could be provided by local agencies, the State Water Project, or the Central Valley Project. The significant point is that any increased delivery of water to the Bay area would be derived from the Central Valley.
- The North Coast HSA will satisfy its future needs from local sources. It is assumed that the north coastal wild and scenic rivers will *not* be available for export from that area. The exception is the Trinity River, which is expected to continue to provide 850,000 acre-feet annually to the Central Valley.
- The North Lahontan, South Lahontan, and Colorado River HSAs include some locations that are scheduled to receive deliveries from the State Water Project. Aside from the SWP, these areas must rely on water supplies within their respective regions to satisfy future needs.
- The Central Valley, consisting of part of the Sacramento, San Joaquin, and Tulare Lake HSAs, is the area projected to experience the greatest increase in net water use over the next 30 years and beyond. The Sacramento HSA is the major source of supply

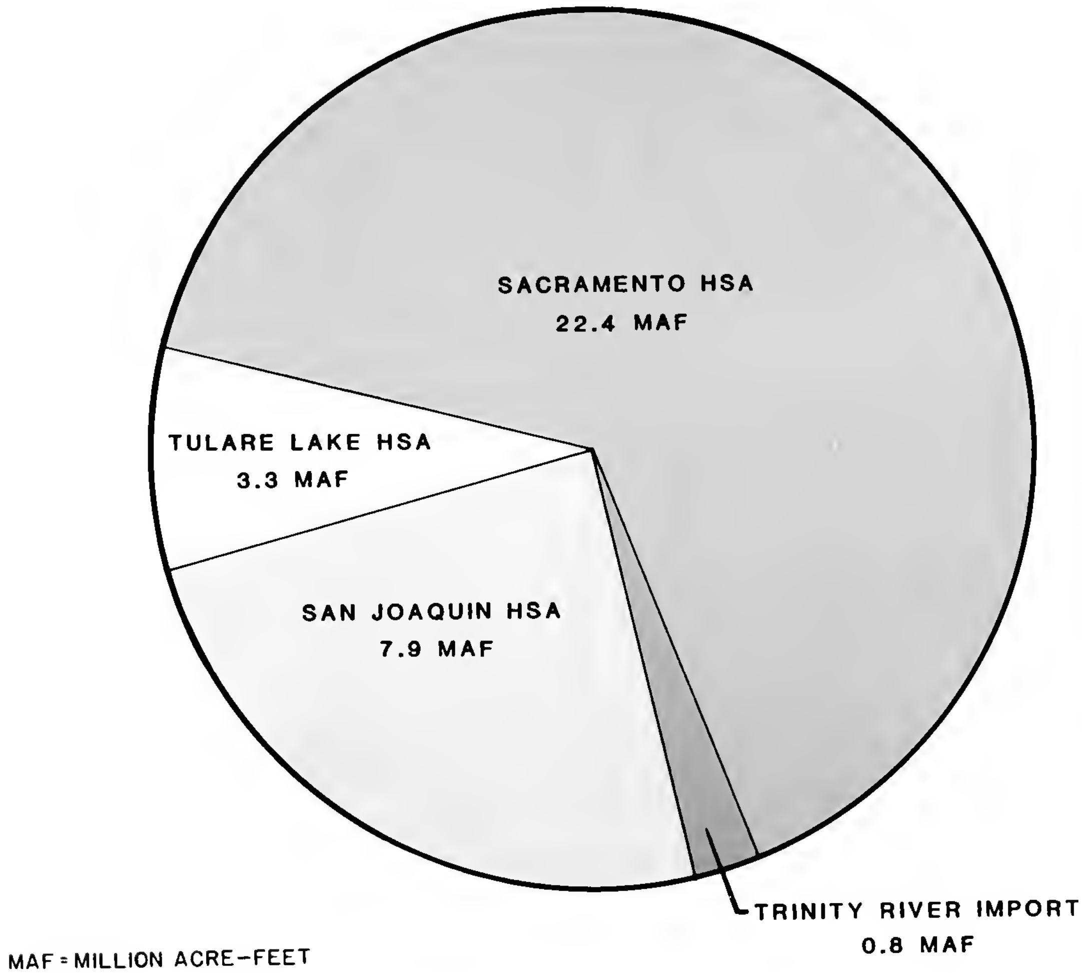
for regions that require additional imported water supplies (including the San Joaquin and Tulare Lake HSAs).

Demands on the Central Valley. Based on the foregoing assumptions, any further increases in water supplies in the South Coastal region and the Central Coast and San Francisco Bay HSAs (with the exception of the city of San Francisco) would come from the Sacramento HSA. The additional needs of the State Water Project will constitute most of the additional export demand on Central Valley sources. In addition, the largest increases in water uses are projected to occur within the Central Valley—the Sacramento, San Joaquin, and Tulare Lake HSAs. From a practical standpoint, the Sacramento HSA is the only reasonable source available to meet the demands of 2010 and at least the immediate decades beyond.

The basic surface water resource within the Central Valley, expressed as mean annual natural runoff, is 33,640,000 acre-feet. This supply is augmented by an average annual import of 850,000 acre-feet from the Trinity River, for a total of 34.5 million acre-feet. This is shown by major areas in Figure 77.

The remainder of this section discusses the availability of the Central Valley water supply in relation to the projected uses of water to be satisfied. Net water

Figure 77. CENTRAL VALLEY SURFACE WATER SUPPLY



uses within the Central Valley are shown in Table 63 for 1980 and for decades to 2010 for the Sacramento HSA and the combined San Joaquin and Tulare Lake HSAs. The areas dependent on exports from the Central Valley water resources are combined into a single value. All values are expressed as net water use and are consistent with those in Chapter V.

In addition to surface runoff, precipitation on the Sacramento Valley floor contributes to ground water recharge during wetter years and adds to the total supply. Increased ground and surface water development can satisfy future water needs in the Sacramento HSA, but there is essentially no opportunity for additional surface or ground water yield in the San Joaquin and Tulare Lake HSAs, without additional imported supplies.

The net water use in major areas in the Central Valley in 1980 is illustrated in Figure 78. Net water use in the San Joaquin and Tulare Lake HSAs does not include the 1980 ground water overdraft of 1.2 million acre-feet. The "Unavoidable Delta Outflow" in that figure is defined as the large floodflows that occur during winter months of wet years that could not be captured economically or physically, even with additional reservoir storage in the Sacramento Valley. The item "Remaining Potential Supply," 4.6 million acre-feet, represents the balance of the total Central Valley resource, 34.5 million acre-feet, after all current needs, excluding ground water overdraft, are met. This also represents the limit of future water development in the valley.

Water Supply Options

This section discusses the sources of water supplies, both surface and ground water, that could be available to satisfy projected needs. For new water supplies, it will not be a case of the use of one or more sources to the exclusion of others, but rather will probably be a combination of all sources.

Surface Water

The California Water Plan of 1957 demonstrated that California had more than sufficient developable water resources, after providing favorable conditions for fish and wildlife, to satisfy potential ultimate urban and agricultural uses; however, it was recognized that certain of the required works would be extremely costly and that their need might never materialize.

North Coast. Streams on the North Coast could provide sources of water to satisfy statewide needs for urban and agriculture purposes beyond 2010. However, wild and scenic instream laws, costly dams, and long and costly conveyance systems keep the North Coast streams from being potential sources of water supply in the foreseeable future.

Sacramento Valley. Most streams in this area have been intensively developed to provide water for urban and agricultural use. If the funding situation improves, prospects seem reasonable that, by 2000, the Cottonwood Creek and Auburn Dam Projects could be constructed and some local development of new water supplies could be completed. These developments probably could provide a total new water yield of about 500,000 acre-feet. Also, an enlarged Shasta Reservoir with a potential new dry-period yield of about 1.4 million acre-feet probably could be completed by 2010 to provide a water supply beyond that date.

Delta Transfer Facility. The amount of export water available could be substantially increased with a Delta transfer facility. More than 20 years of intense effort has been made to identify the type of facility that should be constructed to convey surplus water to the Delta pumps for export to water-deficient areas. The Peripheral Canal could have solved most issues, including fish and wildlife, water supply, water quality, recreation, and shipping. However, the rejection of Proposition 9 left the transfer issue unresolved. Until a Delta transfer facility is provided, full use cannot be made of the available surplus water supplies of the Sacramento Valley.

Colorado River. Reduction in losses of Colorado River water now serving the Coachella and Imperial Valleys might increase the supplies available to the South Coastal region. However, there are signifi-

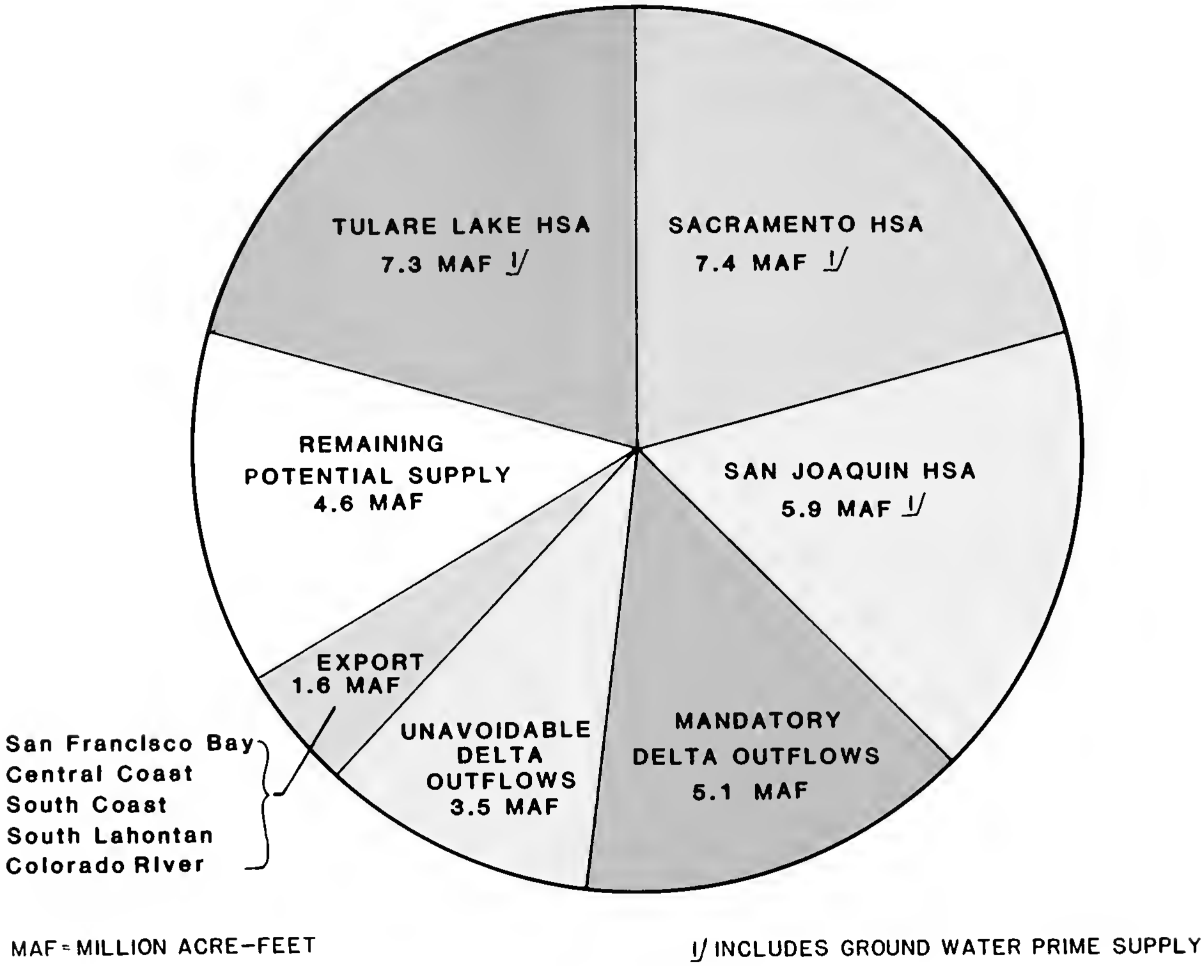
TABLE 63

PRESENT (1980) AND PROJECTED FUTURE NET WATER USES DEPENDENT ON CENTRAL VALLEY WATER RESOURCES [1]
(In millions of acre-feet)

HSA	*1980*	*1990*	*2000*	*2010*
Sacramento	7.5	7.9	8.0	8.2
San Joaquin and Tulare Lake	14.5	15.0	15.4	16.0
San Francisco Bay, Central Coast, Los Angeles, Santa Ana, San Diego, South Lahontan, and Colorado River	1.6	2.5	2.6	2.8
Total	23.6	25.4	26.0	27.0
Increase from the Present (1980)	—	+1.8	+2.4	+3.4

[1] Excluding consideration of mandatory Delta outflows

Figure 78. PRESENT USE OF DEPENDABLE SUPPLY



cant legal and institutional matters that must be resolved before this option can be exercised.

Ground Water

Ground water in storage is the major fresh water reserve in California. Water storage capacity of the major ground water aquifers totals over 1.0 billion acre-feet; by comparison, the total surface reservoir storage capacity is less than 40 million acre-feet. More than 850 million acre-feet of fresh water is stored in the ground water basins, about 500 million acre-feet of which may be usable. Sea-water intrusion, water quality, and surface subsidence are some of the factors affecting usability.

Sacramento Valley. This ground water basin has not been developed to the full extent of its potential because the area is oriented primarily to the use of surface water. The physical potential exists for developing supplemental yield. This ground water supply could be used for local purposes, particularly during dry years, permitting surface water to flow to the Delta for transfer to water-deficient areas. The basin could easily be recharged during ensuing wetter years, resulting in an increase in total developed supply.

San Joaquin Valley. The valley contains the largest ground water basin in the State, with more than 200 million acre-feet of water in storage within 500 feet of the surface. Ground water in these areas has been mined heavily to compensate for a shortage of surface supplies, and there is currently more than 30 million acre-feet of usable empty storage capacity. The principal method of increasing the supply in this area is transferring surplus surface water from the Delta during wetter years to recharge the basin, either by direct recharge or indirectly by using the im-

ported supply in lieu of ground water pumping. Transfer of surface flows would be accomplished by conveyance facilities of the CVP or SWP.

Increasing ground water recharge in the San Joaquin Valley will depend on availability of Sacramento Valley surplus supplies. However, transfer of these supplies has two physical limitations: transfer across the Delta and aqueduct capacity. The San Joaquin Valley ground water basin is in a state of overdraft and is being studied by the Department to develop a conjunctive use management plan. A Department report, *The Hydrologic-Economic Model of the San Joaquin Valley* (Bulletin 214, December 1982), describes the current state of the basin and the modeling systems developed to aid in analyzing operation alternatives for conjunctive management of the ground water resources with surface supplies.

South Coastal Region. This area is of particular importance because it offers the potential for increased use of underground storage capacity in areas of high water use, especially in Orange, Los Angeles, Riverside, and San Bernardino Counties. However, greater use of ground water storage in these areas requires long distance delivery of surplus surface water during wet years from the Sacramento-San Joaquin Delta or possibly the Colorado River. Considerable vacant storage space is available, but the problems of limited aqueduct capacity and the large amounts of energy required for pumping the water to the storage basins cloud the future of actions to enhance the yield of these basins. Additional degradation of ground water quality could occur with widespread recharge, using the saltier Colorado River water. However, the local ground water management agencies can draw on extensive experience in ground water management in developing plans for optimum operation.

South Bay Area. With its proximity to the Delta and with the federal San Felipe Project and the SWP South Bay Aqueduct for delivery, this area offers some opportunity for increased use of ground water.

Santa Ana River spreading grounds, a typical ground water recharge operation. Local runoff regulated by Prado Reservoir is replenishing the Orange County ground water basin. The facility could be used in summer to spread surplus SWP water, when it is available.

This use would augment an already extensive ground water recharge program that has been practiced in the Santa Clara Valley for many years.

Conjunctive Use

Surface water storage projects can be operated in conjunction with ground water basins to develop additional project yield (described in Chapter III). The objective is to operate the surface reservoirs to maximize their yield and reduce ground water use during wetter years and to augment surface supplies with ground water during dry years. As is the case with other future supplies, the surface water supply must come from the Sacramento HSA, and a Delta transfer facility is required to realize the full potential of such a program.

Water Reclamation

California reclaims more waste water than does any other state. Plans are under way to expand reclamation of urban waste water and brackish agricultural drainage water. However, estimating future quantities of reclaimed water is difficult due to a complex set of constraints—principally public health concerns. As circumstances change and more is known about possible health risks and other factors, use of reclaimed water may receive greater public acceptance.

In addition, certain incentives encourage the evaluation of future possibilities of integrating reclaimed waste water into the overall water supply picture. Increased reuse of urban waste water for purposes such as landscaping would free potable supplies for higher uses, thus improving the water supply situation. Transportation costs would be sharply reduced in the southern region of the State by use of locally reclaimed supplies.

One such project is a 15-million-gallon-per-day advanced waste-water treatment plant operated by the Orange County Water District. The plant produces injection water for use in reducing intrusion of sea water into the ground water supply. This project, which is known as Water Factory 21, includes a number of advanced treatment steps. To meet the water quality requirements for injection, one third, or 5 million gallons, of the daily production of treated waste water is also desalted, using a reverse osmosis desalting system. While larger plants do exist elsewhere, this is the largest desalter in the world operating with treated municipal waste for its feed supply.

A major plan for Los Angeles and Orange Counties for the reuse of waste water was completed last year (1982). The Orange and Los Angeles Counties Water Reuse Study was an effort to determine how best to incorporate water reuse into the water supply of the area. The study identified 45 projects that could possibly be implemented over a 30-year period. The aggregate capacity of the 45 projects is about 250,000 acre-feet per year. Following up on a recommendation produced by the study, The Metropolitan Water District of Southern California (MWD) solicited local project proposals from its member agencies. MWD selected 26 proposals for its Phase I demonstration program. The local projects could produce 42,000 acre-feet per year of new yield. MWD has approved funding for some of these local projects, which involve several thousand acre-feet per year of water reuse.

The Monterey Regional Water Pollution Control Agency is evaluating possibilities for using treated municipal waste water for irrigated agriculture in Castroville. It is conducting a seven-year study that will be completed in 1986. The study compares both health effects and crop production in pilot agricultural test plots irrigated with (1) filtered secondary treated effluent, (2) coagulated and filtered secondary treated effluent (as required by Title 22 of the California Administrative Code), and (3) conventional ground water supplies. A progress report on two years of the field studies, issued in the summer of 1982, shows little difference in crop production with the different types of water. Also, reclaimed waste water does not present a public health problem. Further favorable results from this study could lead to additional uses of waste water for agriculture beyond those presently contemplated.

Brackish Agricultural Drainage Water. The Department of Water Resources is investigating the feasibility of desalting agricultural drainage water. The Department is constructing a demonstration desalting facility at Los Banos with a desalting capacity of 344,000 gallons per day. The plant will be used to develop data for preliminary designs and cost estimates for a desalting plant to produce a nominal 25,000 acre-feet per year. Although the Los Banos facility is based on years of pilot plant developmental work, many of the answers on cost and production rates will not be available until at least 1985.

Desalting (Sea-Water Conversion)

Desalting of sea water has at various times been suggested as a means of providing additional water supplies for California, especially at sites near the Pacific coast. Improvements in desalting technology continue to be made, but the cost of water produced is still considerably higher than that of alternative supplies. At the present time, additional surface water supplies can be developed and delivered to major water-short areas in the state at less cost than providing desalted sea water. However, the high cost of importing fresh water to some isolated coastal locations may provide economic justification for using desalted sea water at those sites.

Weather Modification

In California, weather modification programs are concerned with increasing rain and snow from existing storm systems. Although the overall potential of weather modification to amplify the usable statewide water supply appears limited, results of considerable scientific study conducted to date indicate that augmentation can be achieved in varying degrees in some but not all storm events.

One drawback is that precipitation enhancement is needed most during dry years when opportunities to seed clouds are fewer. In wetter years, when storms develop more often, the increased runoff produced artificially would require adequate regulatory reservoir storage to ensure that it could be conserved for later use. However, the potential to increase precipitation by cloud seeding and the low cost of seeding, particularly from ground-base generators, has provided sufficient inducement in recent years to 13 agencies to conduct programs under operations permits.

In 1961, the federal government began working on Project Skywater, a leading precipitation management research program. One Skywater program, the Sierra Cooperative Pilot Project, operates in California. It is a winter cloud-seeding experiment in or near the American River basin that is attempting to determine the best way to seed mountain clouds. Results indicate there could be significant precipitation increases in the Sierra Nevada. However, more study is needed to establish how much an operational program could increase usable water supplies.

While the direct environmental effects of the seeding agents—whether silver iodide or dry ice—are minimal, some detriment may result from changing the amount and intensity of precipitation. Continuing research and careful analysis of the results are aimed at identifying and then either mitigating or eliminating possible negative elements of weather modification techniques.

Vegetation Management

Vegetation management could make more water available by removing high-water-using vegetation of no economic value. The recent development of prescribed burning techniques has intensified interest in managing chaparral, a community of woody-stemmed perennial plants. The helitorch, a device suspended from a helicopter, ignites and drops burning jellied gasoline and greatly reduces the cost of brush removal. Helitorching can be carried out under weather and fuel moisture conditions that reduce the need for fire lines and standby firefighters. This greatly lowers program costs.

The 1980 Legislature authorized a State program of chaparral management for fire prevention, watershed management, range improvement, forest improvement, and wildlife habitat improvement, with a provision for cost-sharing with landowners. This program supplements the State Range Improvement Program, which has been in operation since 1945.

Chaparral is estimated to cover about 20 million acres of land in California. An estimated 5 million acres of chaparral could be managed under the State program; in addition, federal agencies are developing management programs for federal lands. The total statewide programs could ultimately reach about 8.4 million acres. However, there is no large-scale program for analyzing the effects of management programs to determine their economic effectiveness in increasing water yield.

Nonstructural Water Supply Options

Careful management and efficient use of already-developed supplies can delay the need to construct additional water supply projects. The following essentially nonstructural proposals offer the opportunity to optimize use of existing water supplies, particularly during drought periods or other times of deficient supply.

Water Transfers

Water transfers involve changing the type or place of use from one location to another, on either a short-term or long-term basis. Transfers do not augment statewide supplies because no new water supply is created; however, they provide the opportunity to shift water to more seriously affected areas during such times of crisis as drought periods, or to allocate water among uses.

The 1976–1977 drought focused attention on possibilities for temporary transfers of water to areas with serious water shortages. Also, in 1978, the Governor's Commission to Review California Water Right Law recommended that water transfers be encouraged as one method of responding to needs during very dry conditions. Since that time, transfers have received more attention. Over the past few years, numerous informal transfers have been made. However, legal and institutional barriers to transfers would need to be overcome before widespread implementation could be possible.

In 1982, Assembly Bill 3491 [2] was signed into law. It amended the California Water Code to provide greater incentives and a regulatory procedure for water transfers. The legislation directs the Department and the State Water Resources Control Board to encourage voluntary transfers and provides for transfers of water up to a period of seven years under conditions approved by SWRCB. The law also allows water that is made available by conservation or recla-

[2] Amended Water Code Sections 109, 1010, 1011, and 1427, new Sections 380–387, 1435–1442

mation measures to be transferred or sold. Transfers lasting longer and a more "permanent" transfer system will require additional legislation and appropriate physical facilities. Beyond that, there are certain socioeconomic, institutional, and environmental considerations associated with transfers that must be considered.

In the past few years, much has been written about the possibility of establishing a market approach to water transfers; that is, to put water up to the highest bidder. However, this would conflict in many areas with California's existing water rights structure and could have adverse impacts on other water users and instream beneficial uses. While California law provides that no transfers may take place that injure other water users, potential adverse impacts may be difficult to determine. The most likely impact may occur when the water transfer took place upstream of other water users and downstream water users are deprived of return flow from lands which transferred the water.

In an economic sense, a market system should improve the lot of both buyer and seller. The buyer should gain because he acquired something he needs and will profit from; the seller should gain because he received more in return than had he put the resource to his own use. However, there is concern that such transactions may not adequately compensate those not directly involved in the buying and selling process (farm laborers, food processors, retailers, and the like). Where theoretical economists may view the market as a means of realizing efficiency, others see equity questions, including the treatment or nontreatment of instream uses in a market situation. Questions are being also raised as to whether a market concept would really result in the highest and best use of the resource. It may be more a sign of comparative purchasing power among sectors than an optimum use pattern for the benefit of the whole society. The urban sector, for example, could probably outbid agriculture for a given water supply; but water used to water lawns or wash cars may be of less economic and social value than water used to produce food.

The problem is really not with short-term drought-related transfers but in the long-term sale or lease of a property right in water. Further study of this matter is necessary to properly evaluate the ramifications of long-term transfers.

Supply Dependability and Risk

The thrust in California water development over the past few decades has been to increase water supplies to match needs, and in many areas, to increase the dependability of supplies. Much attention has been given to this by the SWP and the CVP, which were designed to withstand reoccurrence of the 1928–1934 drought. Projects, facilities, and programs of other agencies have similar built-in-risks. But uncertainty regarding the capability of increasing developed supplies over the next several decades may justify and in fact may require taking greater risks in delivering water to customers.

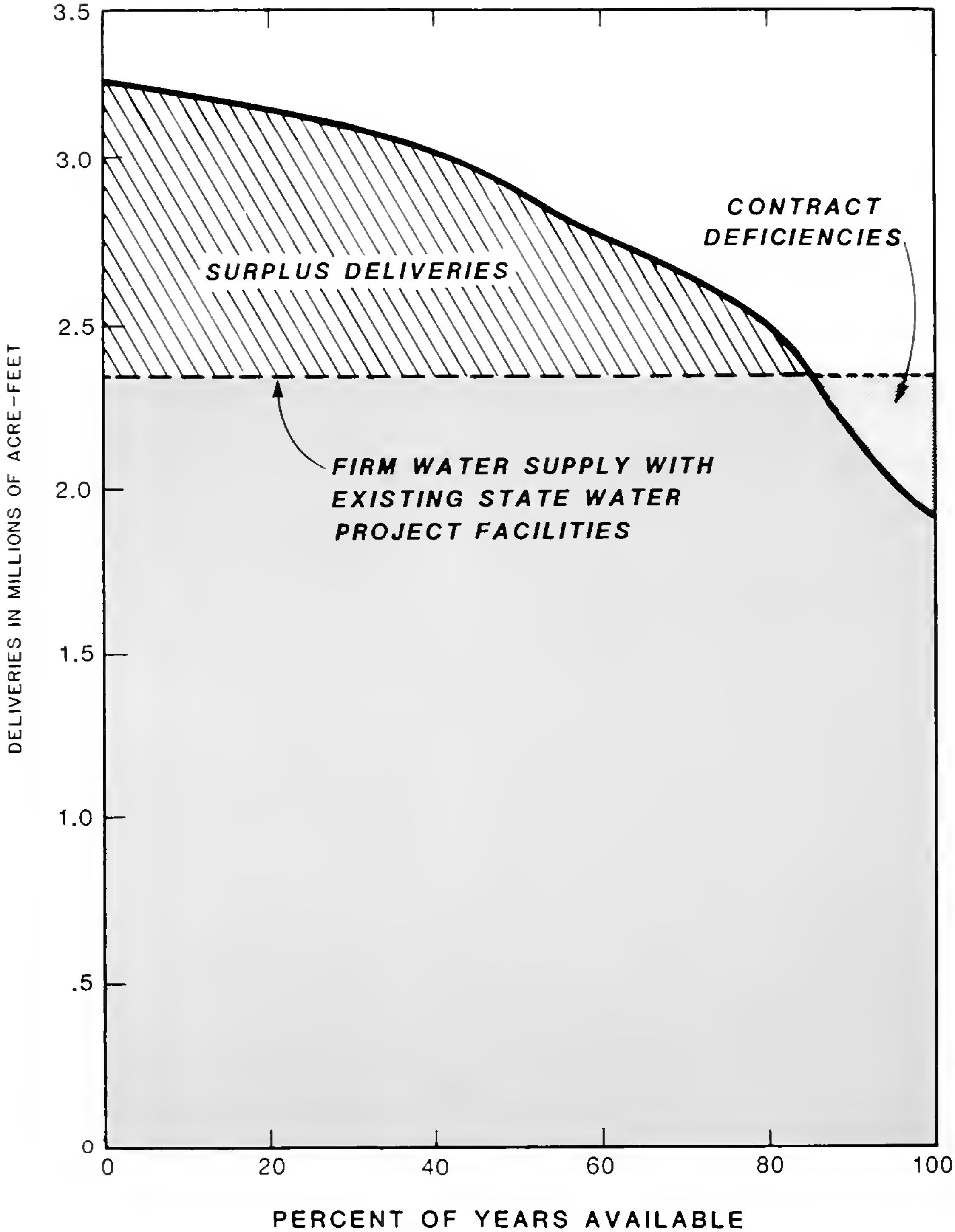
Selection of the 1928–1934 drought to evaluate yield was not based on the relation of drought frequency to cost of facilities. Rather, it was based on the fact that both the CVP and SWP received popular support following the 1928–1934 drought, and Californians wanted the projects to provide essentially a full supply during the entire drought, regardless of its frequency of reoccurrence. Of course, during normal and above-normal years, projects can deliver much more water than is defined as yield under this criterion. Surface water projects of other agencies use different yield-determining dry periods, but the concept is the same. This operational procedure works well where adequate water supplies are already developed to meet existing and future uses. Unfortunately, the State's water uses are outpacing the rate at which increased supplies are being added.

Some water projects would take greater risks by delivering a higher annual supply, leaving less carryover storage in case of drought. This would allow growing needs to be met in normal years. While the final answer lies in what nature will actually provide, there is a good argument that, in the present era of uncertainty regarding future water development, given the frequency of reoccurrence of droughts, existing facilities may be operating in a more conservative manner than is necessary. The 1928–1934 dry period is estimated to have a reoccurrence of one in 200 to 400 years. However, such dry periods could occur in successive decades. Nevertheless, with such a small frequency probability, it may be that projects should take a greater risk and deliver a higher annual average supply. This is illustrated on Figure 79, which depicts a typical operation for the State Water Project to meet demands for 2000, using existing facilities.

Water Conservation

As discussed elsewhere in this report (in particular, under the section titled "Water Supply Savings from Water Conservation" in Chapter IV), water conservation efforts may or may not actually reduce the quantity of water supply needed, depending on how much reuse can be made of the excess applied water. The projections of water use presented in this report reflect the level of water conservation activities (and the amount of related water supply savings) considered most likely to occur on a regular, nonemergency basis. A specific cost-effectiveness determination or benefit-cost analysis was not made for this report. As with the population projections, the land use assumptions, and other long-range fore-

Figure 79. WATER SUPPLY CAPABILITY
STATE WATER PROJECT WITH 1982 FACILITIES



casts, these projections of water conservation are not viewed as the only possible set of answers, however.

The experience of the 1976–1977 drought demonstrates that significant additional urban water conservation effort is possible in emergency situations, although there has been a tendency to return to past levels of use when sufficient supplies once more become available. What the public perceives as extreme measures, compared to what may be considered an acceptable extension of conservation measures assumed in this report, remains to be determined. However, when convinced of the need and equity of proposed actions, the public has demonstrated a willingness to cooperate not only during droughts but in certain situations where water shortages are a long-term prospect.

For irrigated agriculture, results of surveys by the Department and others are consistent in finding that increases in irrigation efficiency beyond that assumed in this report are possible in many areas and that investment to accomplish them will be made if benefits can be demonstrated. Where incentives do not currently exist or are not recognized, government may influence additional increases by education and technological development of applicable measures and by provision of such economic incentives as tax breaks, loan programs, or more direct participation in the risks through government-sponsored programs.

Costs of the greater conservation efforts have not been determined. Consequently, cost comparisons with other alternatives or a determination of their justification are not possible. But, even more important, further analysis of actual water supply savings is required before program feasibility can be determined. Water savings from conservation measures depend on reductions in evapotranspiration and/or outflow (or percolation) to unusable saline water. These can be determined only on a case-by-case basis. The net result is that the amount of water actually saved as a result of conservation varies statewide, depending on the hydrologic characteristics of each area (see Chapter IV, Table 54).

Project Costs and Financing

The increasing cost of new water development is a major consideration in water management. Rapidly rising construction and interest costs have made it more and more difficult to finance new water project construction in recent years and have led to a search for new sources of funds and innovative financing methods. The following paragraphs illustrate some aspects of this situation.

Water Project Construction Costs

Costs of constructing water projects have risen significantly faster than overall prices. The Bureau of Reclamation Composite Index of Construction Costs rose 169 percent from 1970 to 1981, while the GNP Price Deflator Index, the base available measure of inflation, rose only 112 percent during the same period. Construction costs are expected to continue to rise at least as fast as overall prices during the next few years.

Moreover, the cost of new water development will continue to increase because the best available damsites have already been developed. For instance, the cost of an acre-foot of yield from Lake Oroville, the original SWP reservoir, is $37 in 1980 dollars, while the cost per acre-foot of yield from the proposed Cottonwood Creek Project of the Corps of Engineers is estimated to be about $218 in 1981 dollars. Figure 80 illustrates the comparative costs of water supply in 1980 dollars for several existing and proposed projects.

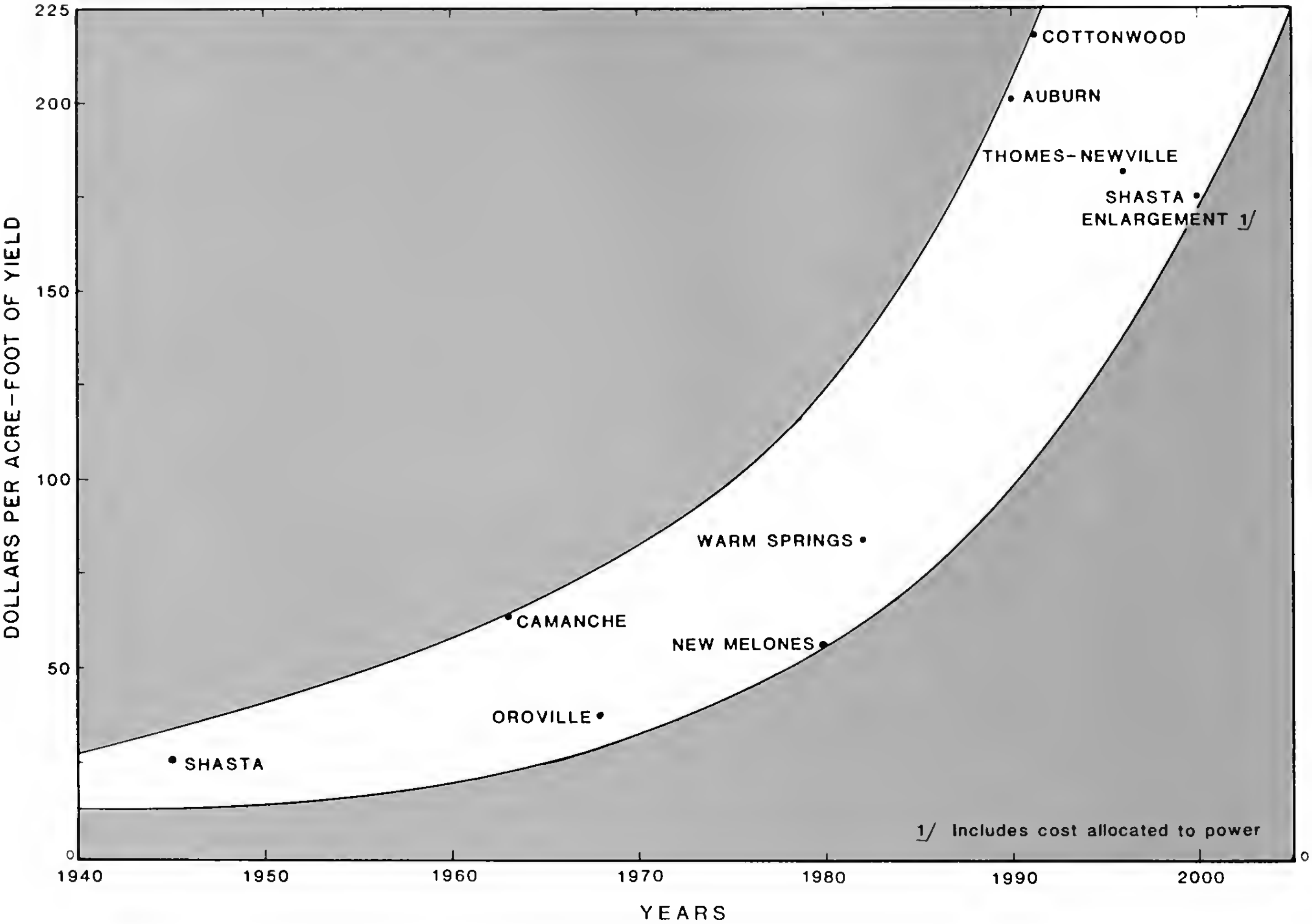
Interest Rates

The record high levels of interest rates in the United States during the past few years have greatly increased the difficulty of obtaining funding of water projects. As an example, the following table shows the impact of the recent rise in interest costs on the State's tax-exempt bonds and notes issued to finance the SWP.

Selected SWP Bond Sales and Interest Rates
1964 to 1982

Date	*Issue Name*	*Effective True Interest Cost (percent per year)*
2/18/64	$100,000,000 Series "A" Water Bonds	3.63
10/22/68	$100,000,000 Series "M" Water Bonds	4.94
2/2/71	$100,000,000 Series "N" Water Bonds	5.67
10/23/79	$95,800,000 Pyramid Hydroelectric Revenue Bonds	7.89
6/30/81	$150,000,000 Reid-Gardner Project, Series A, Bond Anticipation Notes	9.61
12/81	$100,000,000 Bottlerock-Alamo Bond Anticipation Notes	10.04
7/82	$200,000,000 Reid-Gardner Revenue Bonds	12.00
11/82	$200,000,000	10.00

Figure 80. HISTORICAL AND PROJECTED COSTS OF WATER SUPPLY FACILITIES (1980 Dollars)



From the last half of 1980 until the limit was temporarily increased in September 1981, the Department was unable to sell revenue bonds because the bond market rates exceeded the statutory limit of 8.5 percent. Instead, the Department sold three-year bond anticipation notes at relatively high interest costs. The notes were to be redeemed with the proceeds from the sale of long-term revenue bonds when bond market conditions improved. Most other water project sponsors do not have the financing capability of the State and thus have been in even more of a financing dilemma.

Funding and Financing

During the last four decades, California has received federal funds averaging $250 million annually, in 1980 dollars, for water development and flood control. However, in the past decade, the federal government has become less involved in financing new water projects. Proponents of water projects have had to search for alternative sources of funds. Figure 81 illustrates the flow of federal funds for water supply facilities and flood control facilities in constant 1982 dollars over the past 46 years. Figure 82 shows the expenditures that would be necessary in the future, assuming 1982 dollars without inflation and an assumed construction schedule.

Under present policies, federal spending will be reduced and more federal functions will be shifted to state and local governments. On October 12, 1982, the Reclamation Reform Act of 1982 was signed into law. An important element of this Act provides for increased revenue from federal water service contractors in order to recover more costs of existing federal projects. Also, the Bureau of Reclamation has announced that it is seeking to sell some of its existing reclamation projects to the users.

Whatever form cost-sharing finally takes, it appears unlikely that the federal government will, in the near future, at least, provide the level of financial

Figure 81. HISTORICAL FEDERAL RECLAMATION & FLOOD CONTROL APPROPRIATIONS IN CALIFORNIA

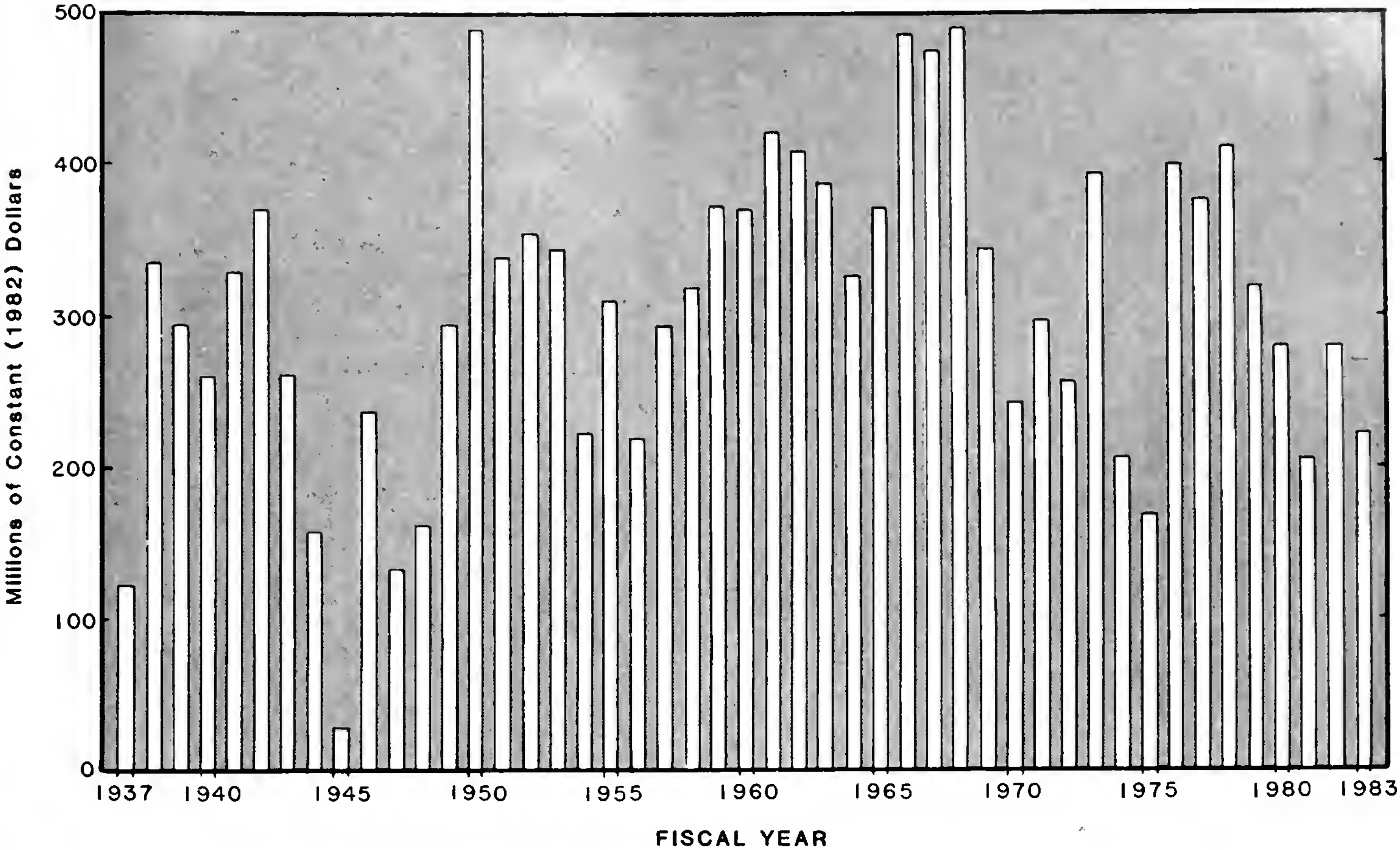
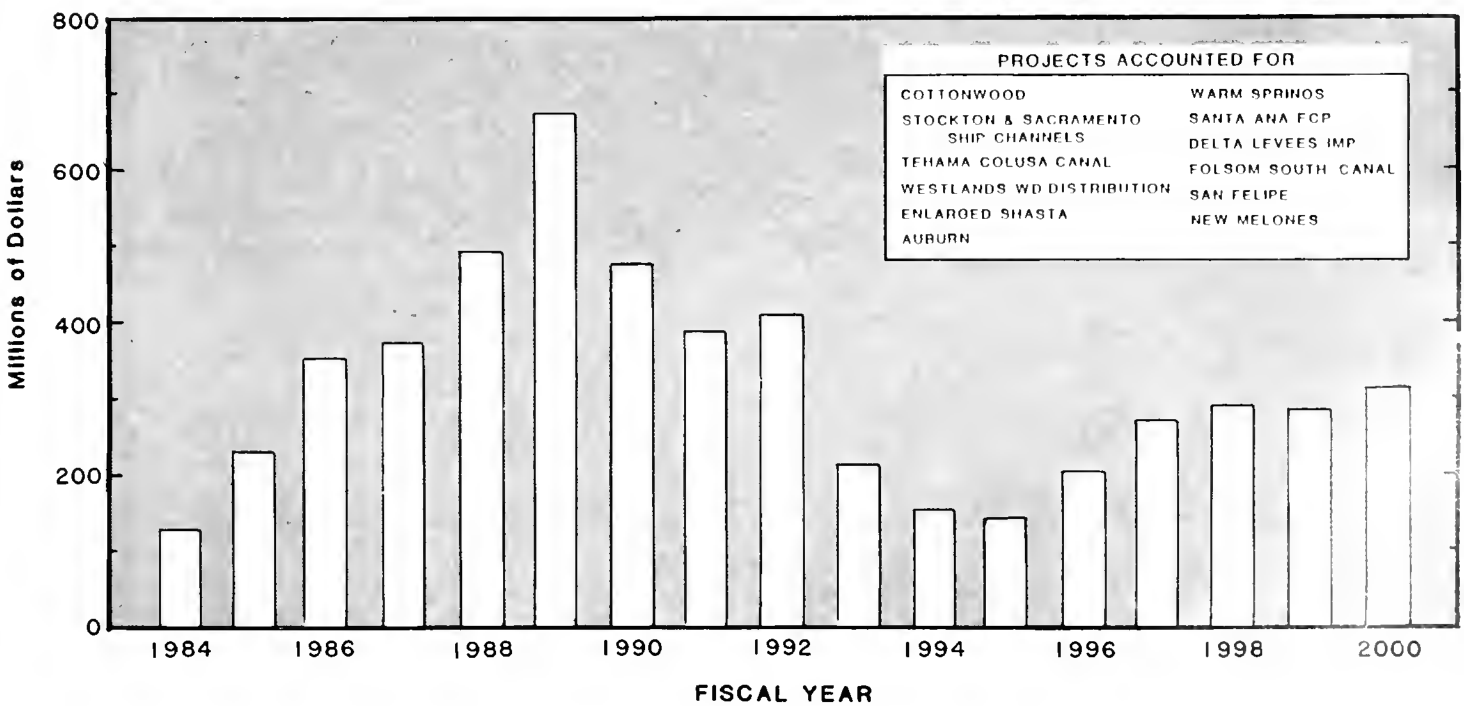


Figure 82. PROJECTED FEDERAL WATER PROJECT APPROPRIATION REQUIREMENTS IN CALIFORNIA

(ASSUMING CONSTRUCTION COST INCREASE AT 2% OVER AVERAGE INFLATION RATE)



support for water development and flood control that it did during the 1940–1980 period. This will require local water agencies and the State to bear considerably more of the burden of financing water projects. This all comes at the same time as the full impact of Proposition 13 (1978), which has severely reduced local tax revenues and is forcing local water agencies to rely on new methods of water project financing.

Water Agency Roles in Water Management

Local, State, and federal water agencies historically have shared the job in California of developing what has become the world's most complex water supply and conveyance system. Now the roles and responsibilities of the various water agencies are changing. Willingness and ability to finance water developments have become critical concerns at all levels of government. Proposed changes in sharing project costs could result in shifts in financial participation and agency responsibilities in planning, construction, and operation of water projects.

The projected water needs presented in this report could be satisfied by the water agencies through some combination of the potential water supply options that have been discussed earlier in this chapter. Surface water could be provided by State and federal water agencies; ground water could continue to be obtained by individuals and increasingly by planned operations of local districts; conservation and reclamation could be undertaken by individuals and water agencies; and short-term transfers of water could be accomplished by all water agencies. All these actions would be in accordance with water law and public water policy.

Local Agencies

Local agencies and individuals are the major suppliers of water for agricultural and urban use, from both underground and surface water sources; however, their development of surface water supplies reached a peak in the 1960s and has since tapered off. Except for a few comparatively small projects, local agencies are presently doing little to provide additional surface water for their needs. The basic reason for this is that the remaining undeveloped sources are limited and development and financing costs are high, generally beyond local financial capability.

Control over ground water supplies occurs essentially at the local and individual level. Proper use of the ground water basins is a matter of wide concern. This has resulted in attempts to change ground water management criteria and policy. These changes, however, are not expected to significantly alter the ground water management role of local agencies. Where conjunctive use operations are involved, State and/or federal agencies will necessarily participate in joint operation programs.

State Agencies

The State Water Project is the most far-reaching of California's water systems. It extends the length of the State and is the key to coordinated water management. Local agencies have contracted for 4.2 million acre-feet of SWP water, and the project currently has a yield of about 2.3 million acre-feet. Plans are being developed to provide the remaining 1.8 million acre-feet as needed.

The limited opportunities remaining statewide for providing new surface water supplies, together with the prospects for reduced development activities by local and federal agencies, make it essential that efforts to better manage California's water resources be intensified. All options must be fully considered. There could be substantial statewide benefits from these efforts. The State must take the lead in working for more harmonious water management by the various water agencies, including exploration of innovative and nontraditional alliances and cooperative efforts.

Federal Agencies

Federal water programs in California have been particularly important. Federal agencies have developed the Central Valley Project and a number of other major storage and conveyance systems. Furthermore, the State's complex flood control systems have either been federally constructed or funded. Also important has been federal funding of many local water supply projects and conveyance systems through loans and grant programs. But federal construction activities that just a few years back were moving forward actively are now proceeding at a greatly reduced pace. Construction and project operation costs are high, opportunities for water development are limited, and reduced funding has slowed water development programs. Proposed changes by federal agencies in cost-sharing would shift more responsibility for water development to nonfederal entities. Nevertheless, federal agencies are expected to continue to have significant roles in managing the State's water resources.

GLOSSARY

GLOSSARY

—A—

ACRE-FOOT—The quantity of water required to cover one acre to a depth of one foot, equal to 3,560 cubic feet or 325,851 gallons. Abbreviation: ac-ft.

ACTIVE STORAGE CAPACITY—The total usable reservoir capacity available for seasonal or cyclic water storage. It is gross reservoir capacity minus inactive storage capacity.

AFTERBAY—A reservoir that regulates fluctuating discharges from a hydroelectric power plant.

ALLUVIUM—A stratified bed of sand, gravel, silt, and clay deposited by flowing water.

ANADROMOUS—Pertaining to fish that spend a part of their life cycle in the sea and return into fresh-water streams to spawn.

ANGLER-DAY—Participation in a fishing activity by one person for any part of a day.

APPLIED WATER—The quantity of water delivered to the intake to a city's water system, the farm headgate, the factory, and, for wildlife, the amount of water supplied to a marsh or other wetland, either directly or by incidental drainage flows.

AQUATIC ALGAE—Microscopic plants that grow in sunlit water that contains phosphates, nitrates, and other nutrients. Algae, like all aquatic plants, add oxygen to the water and are important in the fish food chain.

AQUIFER—A geologic formation that stores and transmits water and yields significant quantities of water to wells and springs.

ARID—A term describing a climate or region in which precipitation is so deficient in quantity or occurs so infrequently that intensive agricultural production is not possible without irrigation.

ARTESIAN—An aquifer in which the water is under sufficient pressure to cause it to rise above the bottom of the overlying confining bed, if opportunity to do so should be provided.

ARTIFICIAL RECHARGE—The addition of water to a ground water reservoir by human activity, such as irrigation or induced infiltration from streams, wells, or recharge basins. See also GROUND WATER RECHARGE, RECHARGE BASIN.

—B—

BENEFITS—Net increase in the value of goods and services which result from the project, as compared to conditions without the project.

BENTHIC INVERTEBRATES—Aquatic animals without backbones that dwell on or in the bottom sediments of fresh or salt water. Examples: clams, crayfish, and a wide variety of worms.

BIOTA—All living organisms of a region, as in a stream or other body of water.

BRACKISH WATER—Water containing dissolved minerals in amounts that exceed normally acceptable standards for municipal, domestic, and irrigation uses. Considerably less saline than sea water.

—C—

CHAPARRAL—A major vegetation type in California characterized by dense evergreen shrubs with thick, hardened leaves.

CLOSED BASIN—A basin whose topography prevents visible surface outflow of water. It is considered to be hydrologically closed if neither surface nor underground outflow of water can occur.

CONFINED AQUIFER—A water-bearing stratum that is bounded above and below by formations of impermeable, or relatively impermeable, material.

CONJUNCTIVE OPERATION—The operation of a ground water basin in coordination with a surface water storage and conveyance system. The purpose is to recharge the basin during years of above-average water supply to provide storage that can be withdrawn during drier years when surface water supplies are below normal.

CRITICAL DRY PERIOD—A series of water-deficient years, usually an historical period, in which a full reservoir storage system at the beginning is drawn down to minimum storage at the end without any spill.

CRITICAL DRY YEAR—A dry year in which the full commitments for a dependable water supply cannot be met and deficiencies are imposed on water deliveries.

—D—

DEEP PERCOLATION—The percolation downward of water past the lower limit of the root zone of plants.

DEPENDABLE SUPPLY (WATER)—The annual quantity of water that can be delivered under normal water supply conditions, and with allowable deficiencies during critical dry periods. See also CRITICAL DRY YEAR, FIRM YIELD, PROJECT YIELD.

DEPLETION (WATER)—Water used and no longer available as a source of supply.

DESALTING—A process that converts sea water or brackish water to fresh water or an otherwise more usable condition through removal of dissolved solids. Also called "desalination."

DETAILED ANALYSIS UNIT (DAU)—The smallest study area used in the analysis of water use and supply, generally defined by hydrologic features or boundaries of organized water service agencies. In the major agricultural areas, a DAU typically includes 100,000 to 300,000 acres.

DISCOUNT RATE—The interest rate used in evaluating water (and other) projects to calculate the present value of future benefits and future costs or to convert benefits and costs to a common time basis.

DISSOLVED OXYGEN—The oxygen dissolved in water, usually expressed in milligrams per litre, parts per million, or percent of saturation. Abbreviation: DO

DOUBLE CROPPING—The practice of producing two or more crops consecutively on the same parcel of land during a 12-month period. Also called multi-cropping.

DRAINAGE BASIN—The area of land from which water drains into a river; as, for example, the Sacramento River Basin, in which all land area drains into the Sacramento River. Also called, "catchment area," "watershed," or "river basin."

—E—

ECOLOGY—The study of the interrelationships of living organisms to one another and to their surroundings.

ECONOMIC DEMAND—The consumer's willingness and ability to purchase some quantity of a commodity based on the price of that commodity.

ECOSYSTEM—Recognizable, relatively homogeneous units, including the organisms they contain, their environment, and all the interactions among them.

EFFLUENT—Waste water or other liquid, partially or completely treated or in its natural state, flowing from a treatment plant.

ENVIRONMENT—The sum of all external influences and conditions affecting the life and development of an organism or ecological community; the total social and cultural conditions that influence the life of an individual or community.

ESTUARY—The lower course of a river entering the sea influenced by tidal action where the tide meets the river current.

EVAPOTRANSPIRATION—The quantity of water transpired (given off) and evaporated from plant tissues and surrounding soil surfaces. Quantitatively, it is expressed in terms of volume of water per unit acre or depth of water during a specified period of time. Abbreviation: ET.

EVAPOTRANSPIRATION OF APPLIED WATER—The portion of the total evapotranspiration which is provided by irrigation. Abbreviation: ETAW.

—F—

FIRM YIELD—The maximum annual supply of a given water development that is expected to be available on demand, with the understanding that lower yields will occur in accordance with a predetermined schedule or probability. See also DEPENDABLE SUPPLY, PROJECT YIELD.

FOREBAY—A reservoir or pond situated at the intake of a pumping plant or power plant to stabilize water levels.

FRY—A very young fish.

—G—

GRAY WATER—All waste water generated within the home or small commercial establishment which does not contain toilet waste.

GROSS RESERVOIR CAPACITY—The total storage capacity available in a reservoir for all purposes, from the streambed to the normal maximum operating level. Includes dead storage, but excludes surcharge (water temporarily stored above the elevation of the top of the spillway).

GROUND WATER—Water that occurs beneath the land surface and completely fills all pore spaces of the alluvium or rock formation in which it is situated.

GROUND WATER BASIN—A ground water reservoir, together with all the overlying land surface and the underlying aquifers that contribute water to the reservoir. In some cases, the boundaries of successively deeper aquifers may differ and make it difficult to define the limits of the basin.

GROUND WATER MINING—The withdrawal of water from an aquifer greatly in excess of replenishment; if continued, the underground supply will eventually be exhausted or the water table will drop below economically feasible pumping lifts.

GROUND WATER OVERDRAFT—The condition of a ground water basin in which the amount of water withdrawn by pumping exceeds the amount of water that replenishes the basin over a period of years.

GROUND WATER PRIME SUPPLY—The long-term average annual percolation to the major ground water basins from precipitation falling on the land and from flows in rivers and streams. Also includes recharge from local source that has been enhanced by construction of spreading ground or other means. Recharge of imported and reclaimed water is not included.

GROUND WATER RECHARGE—Increases in ground water by natural conditions or by human activity. See also ARTIFICIAL RECHARGE.

GROUND WATER RESERVOIR—An aquifer or an aquifer system in which ground water is stored. The water may be placed in the aquifer by artificial or natural means.

GROUND WATER STORAGE CAPACITY—The space contained in a given volume of deposits. Under optimum use conditions, the usable ground water storage capacity is the volume of water that can, within specified economic limitations, be alternatively extracted and replaced in the reservoir.

GROUND WATER TABLE—The upper surface of the zone of saturation (all pores of subsoil filled with water), except where the surface is formed by an impermeable body.

—H—

HARDPAN—A layer of nearly impermeable soil beneath a more permeable soil, formed by chemical cementing of the soil particles.

HEAD DITCH—The water supply ditch at the head end of an irrigated field.

HYDROLOGIC BALANCE—An accounting of all water inflow to, water outflow from, and changes in water storage within a hydrologic unit.

HYDROLOGIC BASIN—The complete drainage area upstream from a given point on a stream.

HYDROLOGIC STUDY AREA (HSA)—The largest study area, consisting of one or more Planning Subareas. It usually encompasses a major stream system drainage area, such as the Sacramento River; a closed hydrologic basin, such as the Tulare Lake HSA; or a regional group of river basins, such as the North Coast or Central Coast HSAs.

—I—

INCIDENTAL WASTE WATER RECLAMATION—Treated waste water returned to fresh-water streams or other water bodies. Additional use made of this treated waste water is only incidental to waste water treatment and disposal.

INSTREAM USE—Use of water that does not require diversion from its natural watercourse. For example, the use of water for navigation, waste disposal, recreation, fish and wildlife, esthetics, and scenic enjoyment.

INTENTIONAL WASTE WATER RECLAMATION—The planned reuse of urban waste water for specific beneficial purposes.

IRRIGATION EFFICIENCY—The efficiency of water application on a farm. Computed by dividing evapotranspiration of applied water (ETAW) by applied water and converting the result to a percentage.

IRRIGATION RETURN FLOW—Applied water that is not transpired or evaporated but that returns to a surface or ground water supply.

ISOHYETAL—Indicating equal rainfall, generally expressed as lines of equal rainfall.

—L—

LAND SUBSIDENCE—The lowering of the natural land surface in response to: earth movements; lowering of fluid pressure; removal of underlying supporting materials by mining or solution of solids, either artificially or from natural causes; compaction caused by wetting (hydrocompaction); oxidation of organic matter in soils; or added load on the land surface.

LASER LAND LEVELING—Use of instruments featuring laser beams to guide earthmoving equipment leveling land for surface-type irrigation.

LEACHING—The flushing of salts from the soil by the downward percolation of water.

LINEAR PROGRAMMING MODEL—A mathematical approach to finding the least cost or maximum return way of using available resources in the production of a good. Linear programming models consist of a set of linear equations that are used to describe the limiting factors and the objective that is sought. Linear programming models are normally solved using computers.

—M—

MEAN ANNUAL RUNOFF—The average value of annual runoff amounts calculated for a selected period of record for a specified area.

MEGAWATT—One million watts.

MILLIGRAMS PER LITRE—The weight in milligrams of any substance dissolved in one litre of liquid. Nearly the same as parts per million. Abbreviation: mg/L.

MOISTURE STRESS—A condition of physiological stress in a plant caused by a lack of water.

MULTIPURPOSE PROJECT—A project designed to serve more than one purpose. For example, one that provides water for irrigation and recreation, controls floods, and generates electric power.

—N—

NATURAL FLOW—The flow past a specified point on a natural stream that is unaffected by stream diversion, storage, import, export, return flow, or change in use caused by modifications in land use.

NET RESERVOIR EVAPORATION—The difference between the evaporation from the reservoir's water surface and the evapotranspiration from the area inundated by the reservoir under conditions that existed before the reservoir was built.

NET WATER USE—The sum of the evapotranspiration of applied water (ETAW) required in an area, the irrecoverable losses from the water distribution system, and the drainage outflow leaving the area.

NONFIRM YIELD—The amount of water from a surface water project that exceeds the long-term firm yield, occurring only periodically as a function of variation in runoff. Sometimes referred to as nonfirm supply.

NONPOINT SOURCE—Waste water discharge other than from point sources. See POINT SOURCE.

NONREIMBURSABLE COSTS—Project costs allocated to general statewide or national beneficial purposes and funded from general revenues.

—P—

PATHOGENS—Any viruses, bacteria, or fungi that cause disease.

PEAK LOAD (POWER)—The maximum electrical energy used in a stated period of time. Usually computed over an interval of one hour that occurs during the year, month, week, or day. The term is used interchangeably with peak demand.

PERCHED GROUND WATER—Ground water supported by a zone of material of low permeability located above an underlying main body of ground water with which it is not hydrostatically connected.

PERCOLATION—The downward movement of water through the soil or alluvium to the ground water table.

PERMEABILITY—The capability of soil or other geologic formation to transmit water.

PHREATOPHYTES—Native plants that typically obtain their water supply directly from the water table or from the capillary fringe immediately above the water table.

PHYTOPLANKTON—Minute plants, usually algae, that live suspended in bodies of water and that drift about because they cannot move by themselves or because they are too small or too weak to swim effectively against a current.

PLANNING SUBAREA (PSA)—An intermediate size study area consisting of one or more Detailed Analysis Unit(s).

POINT SOURCE—A specific site from which waste water is discharged into a water body, the source of which can be identified, as with effluent, treated or not, from a municipal sewerage system, outflow from an industrial plant, or runoff from an animal feedlot. See also NONPOINT SOURCE.

POLLUTION (WATER)—The alteration of the physical, chemical, or biological properties of water by the introduction of any substance into water that adversely affects any beneficial use of water.

PROJECT YIELD—The water supply attributed to all features of a project, including integrated operation of units that could be operated individually. Usually, but not always, it is the same as firm water yield. See also DEPENDABLE SUPPLY, FIRM YIELD.

PUMP-GENERATOR PLANT—A plant at which the turbine-driven generators can also be used as motor-driven pumps.

PUMPED STORAGE PROJECT—A hydroelectric powerplant and reservoir system using an arrangement whereby water released for generating energy during peak load periods is stored and pumped back into the upper reservoir, usually during periods of reduced demand.

—R—

RECHARGE BASIN—A surface facility, often a large pond, used to increase the infiltration of water into a ground water basin.

RECLAIMED WASTE WATER—Urban waste water that becomes suitable for a specific beneficial use as a result of treatment.

RECREATION-DAY—See VISITOR-DAY.

REIMBURSABLE COSTS—Those costs of a water project that are expected to be recovered, usually from direct beneficiaries, and repaid to the funding entity.

RESERVE SUPPLY—Developed but presently unused surface water supply available to certain portions of Hydrologic Study Area to meet planned future water needs; the supply is not usually available to other areas needing additional water because of a lack of physical facilities and/or institutional arrangements. The reserves include the sum of the reserves in each Planning Subarea (PSA) from local development and imports, the SWP and CVP, and other federal development. Not all the total of these reserves is usable because some of it consists of return flows that become part of the downstream reserve supply for a PSA. Some of the reserve supply identified for a PSA may also be included in the amount identified for one or more other PSAs.

RETURN FLOW—The portion of withdrawn water that is not consumed by evapotranspiration and returns instead to its source or to another body of water.

REUSE—The additional use of once-used water.

RIFFLE—A shallow extending across a streambed that causes broken or turbulent water.

RIPARIAN—Of, or on the banks of, a stream or other body of water.

RIPARIAN VEGETATION—Vegetation growing on the banks of a stream or other body of water.

RUNOFF—The surface flow of water from an area; the total volume of surface flow during a specified time.

—S—

SAFE YIELD (GROUND WATER)—The maximum quantity of water that can be withdrawn from a ground water basin over a long period of time without developing a condition of overdraft. Sometimes referred to as sustained yield.

SALINITY—Generally, the concentration of mineral salts dissolved in water. Salinity may be measured by weight (total dissolved solids), electrical conductivity, or osmotic pressure. Where sea water is known to be the major source of salt, salinity is often used to refer to the concentration of chlorides in the water. See also TOTAL DISSOLVED SOLIDS.

SALINITY INTRUSION—The movement of salt water into a body of fresh water. It can occur in either surface water or ground water bodies.

SALT SINK—A body of water too salty for most fresh-water uses.

SALT-WATER BARRIER—A physical facility or method of operation designed to prevent the intrusion of salt water into a body of fresh water.

SECONDARY TREATMENT—In sewage, the biological process of reducing suspended, colloidal, and dissolved organic matter in effluent from primary treatment systems. Secondary treatment is usually carried out through the use of trickling filters or by the activated sludge process.

SEDIMENT—Soil or mineral material transported by water and deposited in streams or other bodies of water.

SEEPAGE—The gradual movement of a fluid into, through, or from a porous medium.

SELF-PRODUCED WATER—A water supply developed and used by an individual or entity. Also called "self-supplied water."

SERVICE AREA—The geographical land area included in the distribution system of a water agency.

SEWAGE—The waste matter from domestic, commercial, and industrial establishments.

SPAWNING—The deposit of eggs (or roe) by fish and other aquatic life.

SPREADING BASIN—See RECHARGE BASIN.

SPREADING GROUNDS—See RECHARGE BASIN.

STREAMFLOW—The rate of water flow past a specified point in a channel.

SURFACE SUPPLY—Developed water supply from streams, lakes, and reservoirs.

SURPLUS WATER—As used in this report, the term refers to developed SWP water supplies in excess of contract entitlement water.

SUSPENDED SEDIMENT—Particles of sediment suspended in a liquid.

—T—

TAIL WATER—See IRRIGATION RETURN FLOW.

TERTIARY TREATMENT—In sewage, the additional treatment of effluent beyond that of secondary treatment to obtain a very high quality of effluent.

TOTAL DISSOLVED SOLIDS—A quantitative measure of the residual minerals dissolved in water that remain after evaporation of a solution. Usually expressed in milligrams per litre. Abbreviation: TDS. See also SALINITY.

TRANSPIRATION—The process in which plant tissues give off water vapor to the atmosphere as an essential physiological process.

—U—

USABLE STORAGE CAPACITY—Ground water storage capacity that is capable of yielding water to wells economically and of being readily recharged.

—V—

VISITOR-DAY—Participation in a recreational activity by one person for any part of a day.

—W—

WASTE WATER—The used water, liquid waste, or drainage from a community, industry, or institution.

WATER CONSERVATION—As used in this report, urban water conservation includes the impact of measures and actions taken from 1975 to 2010; agricultural water conservation includes any increase in irrigation efficiency and related measures after 1980.

WATER DEMAND SCHEDULE—A time distribution of the demand for prescribed quantities of water for specified purposes. It is usually a monthly tabulation of the total quantity of water that a particular water user intends to use during a specified year.

WATER QUALITY—A term used to describe the chemical, physical, and biological characteristics of water, usually in regard to its suitability for a particular purpose.

WATER RECLAMATION—The treatment of water of impaired quality, including brackish water and sea water, to produce a water of suitable quality for the intended use.

WATER REQUIREMENT—The quantity of water required for a specified use under a predetermined or prescribed situation.

WATER RIGHT—A legally protected right to take possession of water occurring in a water supply and to divert that water for beneficial use.

WATERSHED—See DRAINAGE BASIN.

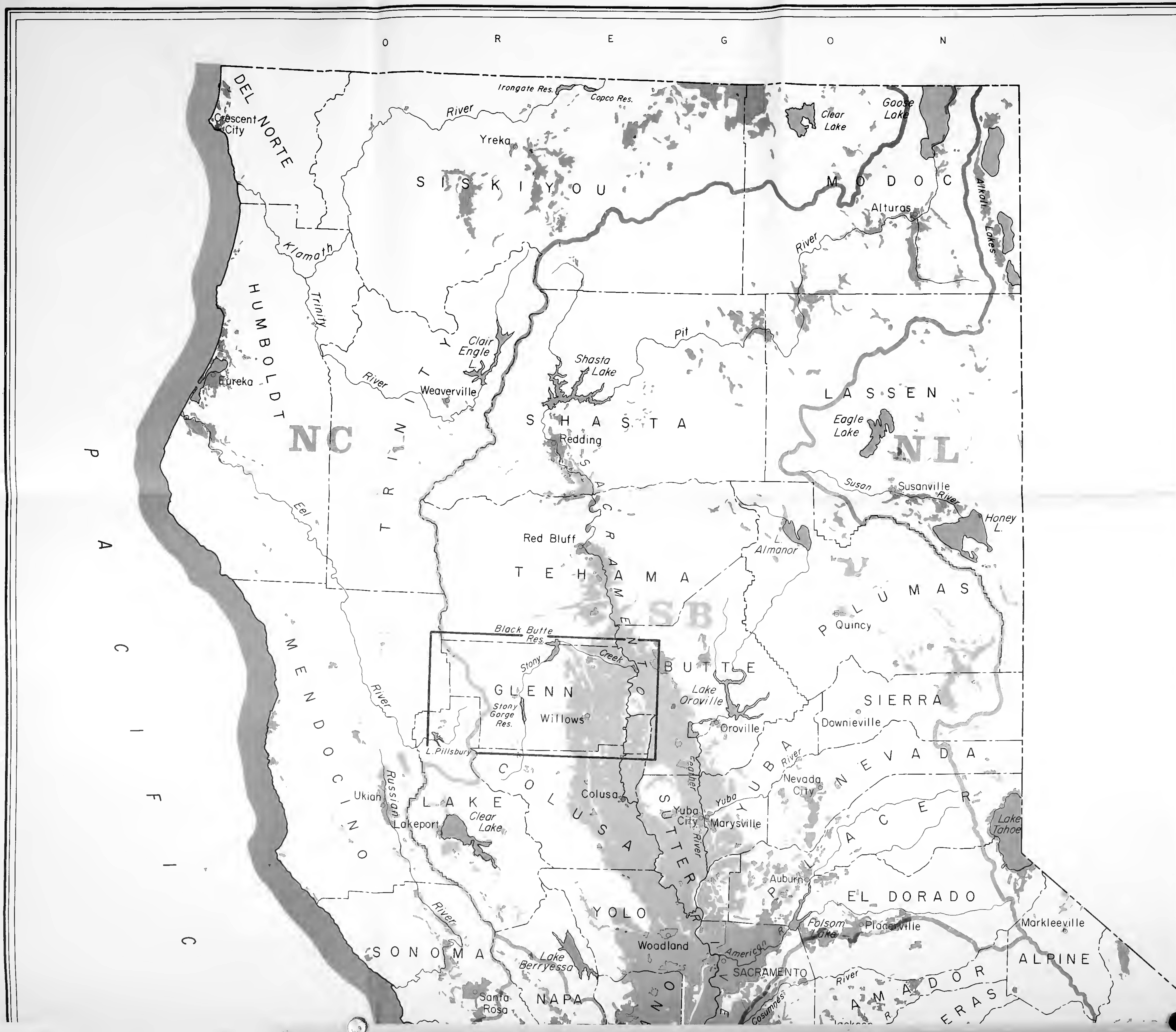
WATER TABLE—See GROUND WATER TABLE.

WATER YEAR—A continuous 12-month period for which hydrologic records are compiled and summarized. In California, it begins on October 1.

CONVERSION FACTORS

Quantity	To Convert from Metric Unit	To Customary Unit	Multiply Metric Unit By	To Convert to Metric Unit Multiply Customary Unit By
Length	millimetres (mm)	inches (in)	0 03937	25 4
	centimetres (cm) for snow depth	inches (in)	0 3937	2 54
	metres (m)	feet (ft)	3 2808	0 3048
	kilometres (km)	miles (mi)	0 62139	1 6093
Area	square millimetres (mm^2)	square inches (in^2)	0 00155	645 16
	square metres (m^2)	square feet (ft^2)	10 764	0 092903
	hectares (ha)	acres (ac)	2 4710	0 40469
	square kilometres (km^2)	square miles (mi^2)	0 3861	2 590
Volume	litres (L)	gallons (gal)	0 26417	3 7854
	megalitres	million gallons (10^6 gal)	0 26417	3 7854
	cubic metres (m^3)	cubic feet (ft^3)	35 315	0 028317
	cubic metres (m^3)	cubic yards (yd^3)	1 308	0 76455
	cubic dekametres (dam^3)	acre-feet (ac-ft)	0 8107	1 2335
Flow	cubic metres per second (m^3/s)	cubic feet per second (ft^3/s)	35 315	0 028317
	litres per minute (L/min)	gallons per minute (gal/min)	0 26417	3 7854
	litres per day (L/day)	gallons per day (gal/day)	0 26417	3 7854
	megalitres per day (ML/day)	million gallons per day (mgd)	0 26417	3 7854
	cubic dekametres per day (dam^3/day)	acre-feet per day (ac-ft/day)	0 8107	1 2335
Mass	kilograms (kg)	pounds (lb)	2 2046	0 45359
	megagrams (Mg)	tons (short, 2,000 lb)	1 1023	0 90718
Velocity	metres per second (m/s)	feet per second (ft/s)	3 2808	0 3048
Power	kilowatts (kW)	horsepower (hp)	1 3405	0 746
Pressure	kilopascals (kPa)	pounds per square inch (psi)	0 14505	6 8948
	kilopascals (kPa)	feet head of water	0 33456	2 989
Specific Capacity	litres per minute per metre drawdown	gallons per minute per foot drawdown	0 08052	12 419
Concentration	milligrams per litre (mg/L)	parts per million (ppm)	1 0	1 0
Electrical Conductivity	microsiemens per centimetre (uS/cm)	micromhos per centimetre	1 0	1 0
Temperature	degrees Celsius (°C)	degrees Fahrenheit (°F)	(1 8 × °C)+32	(°F−32)/1 8

PLATE 2

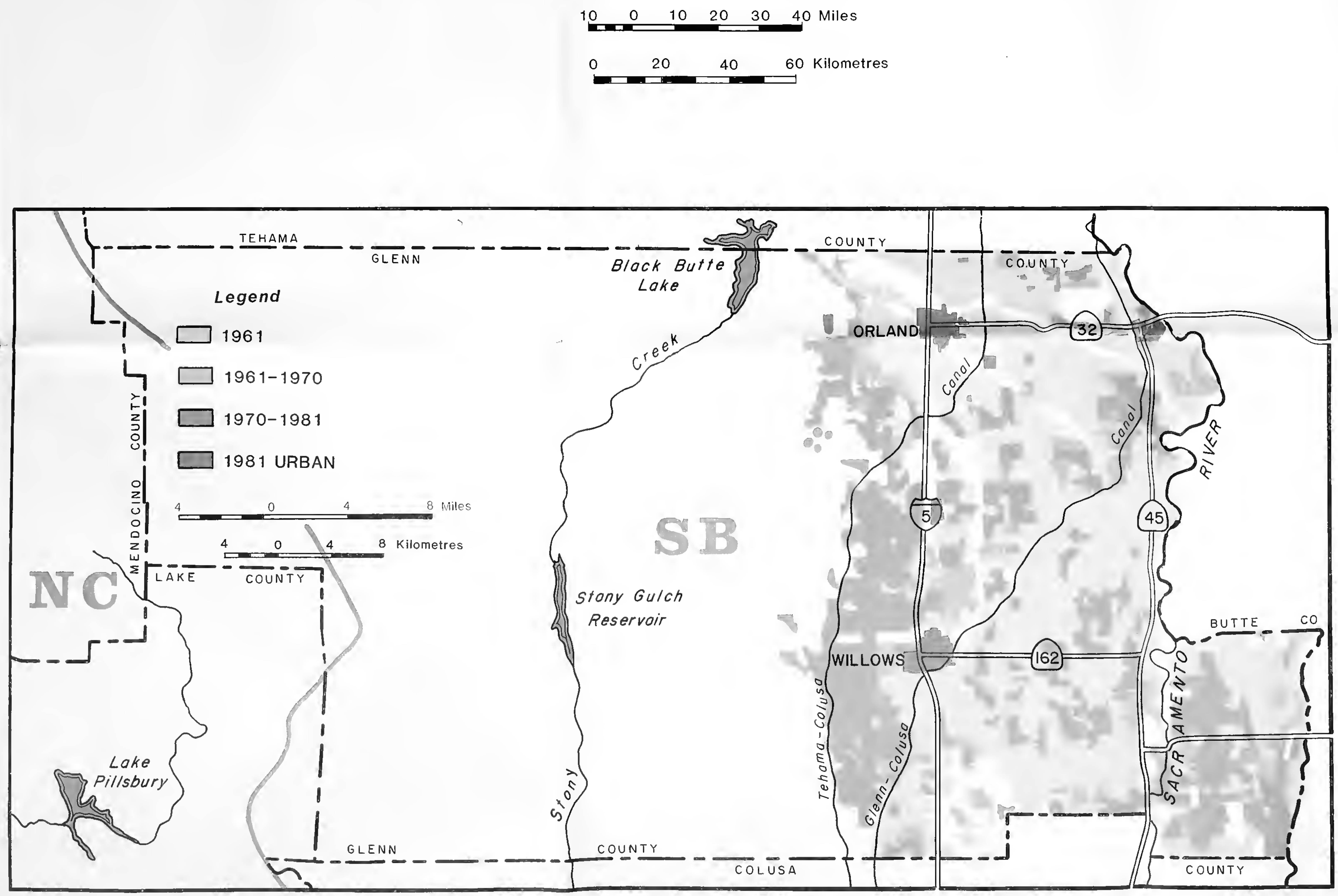


O R E G O N
P A C I F I C
DEL NORTE
Crescent City
Irongate Res.
Copco Res.
River
Yreka
SISKIYOU
Clear Lake
Goose Lake
MODOC
Alturas
Alkali Lakes
Klamath
Trinity
HUMBOLDT
Eureka
Clair Engle L.
River
Weaverville
TRINITY
Shasta Lake
Pit
SHASTA
Redding
LASSEN
Eagle Lake
NL
NC
Susan
Susanville
River
Honey L.
Eel
Red Bluff
L. Almanor
TEHAMA
SACRAMENTO
SB
PLUMAS
Quincy
Black Butte Res.
Stony
Creek
BUTTE
GLENN
Stony Gorge Res.
Willows
Lake Oroville
Oroville
SIERRA
Downieville
MENDOCINO
River
L. Pillsbury
COLUSA
YUBA
River
NEVADA
Nevada City
Russian
Ukiah
LAKE
Clear Lake
Lakeport
Colusa
Feather River
Yuba
Yuba City
Marysville
SUTTER
PLACER
Lake Tahoe
Auburn
EL DORADO
YOLO
River
Woodland
American R.
Folsom Lake
Placerville
Markleeville
SONOMA
Lake Berryessa
SACRAMENTO
River
ALPINE
AMADOR
Cosumnes
Santa Rosa
NAPA

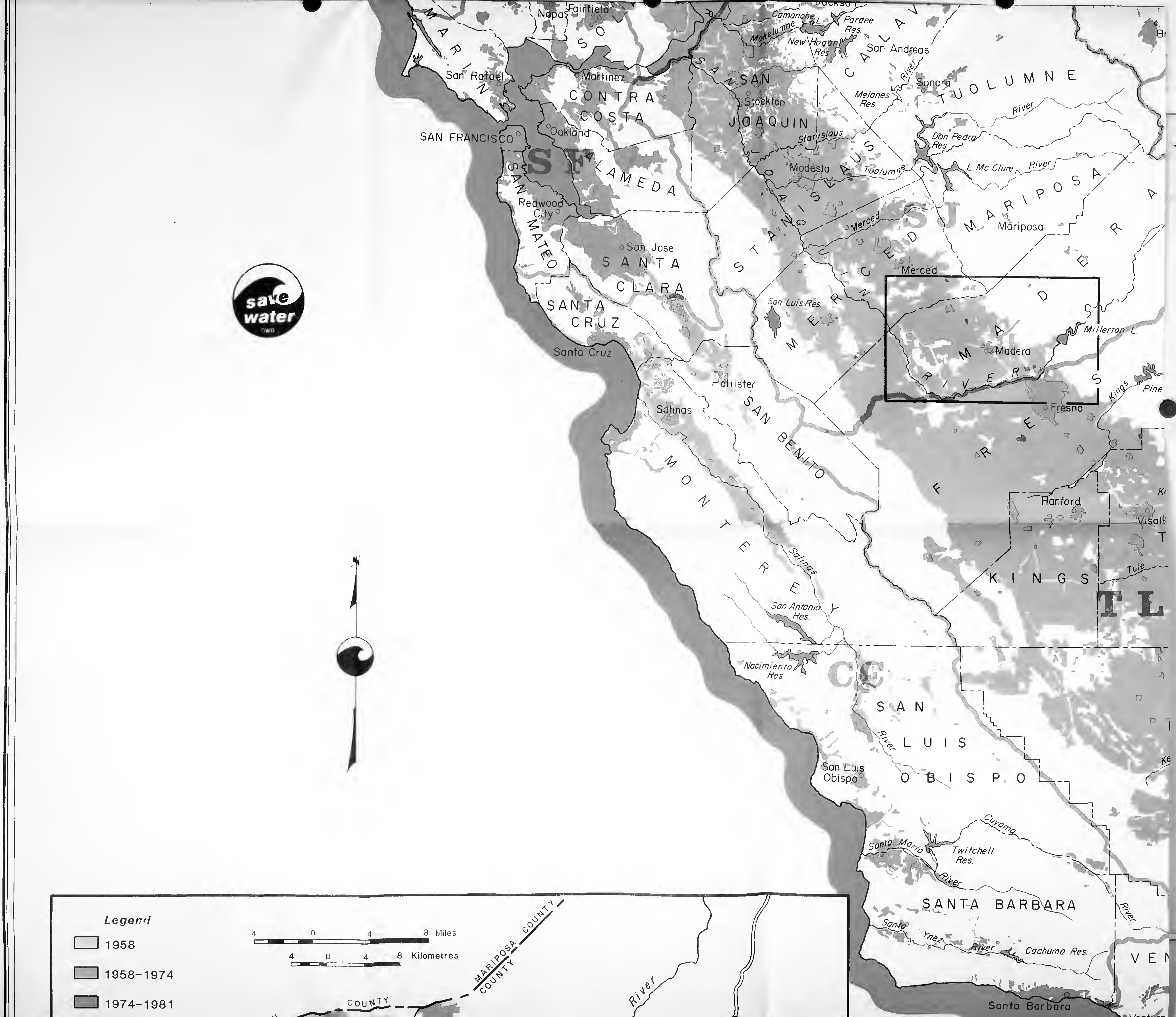
State of California

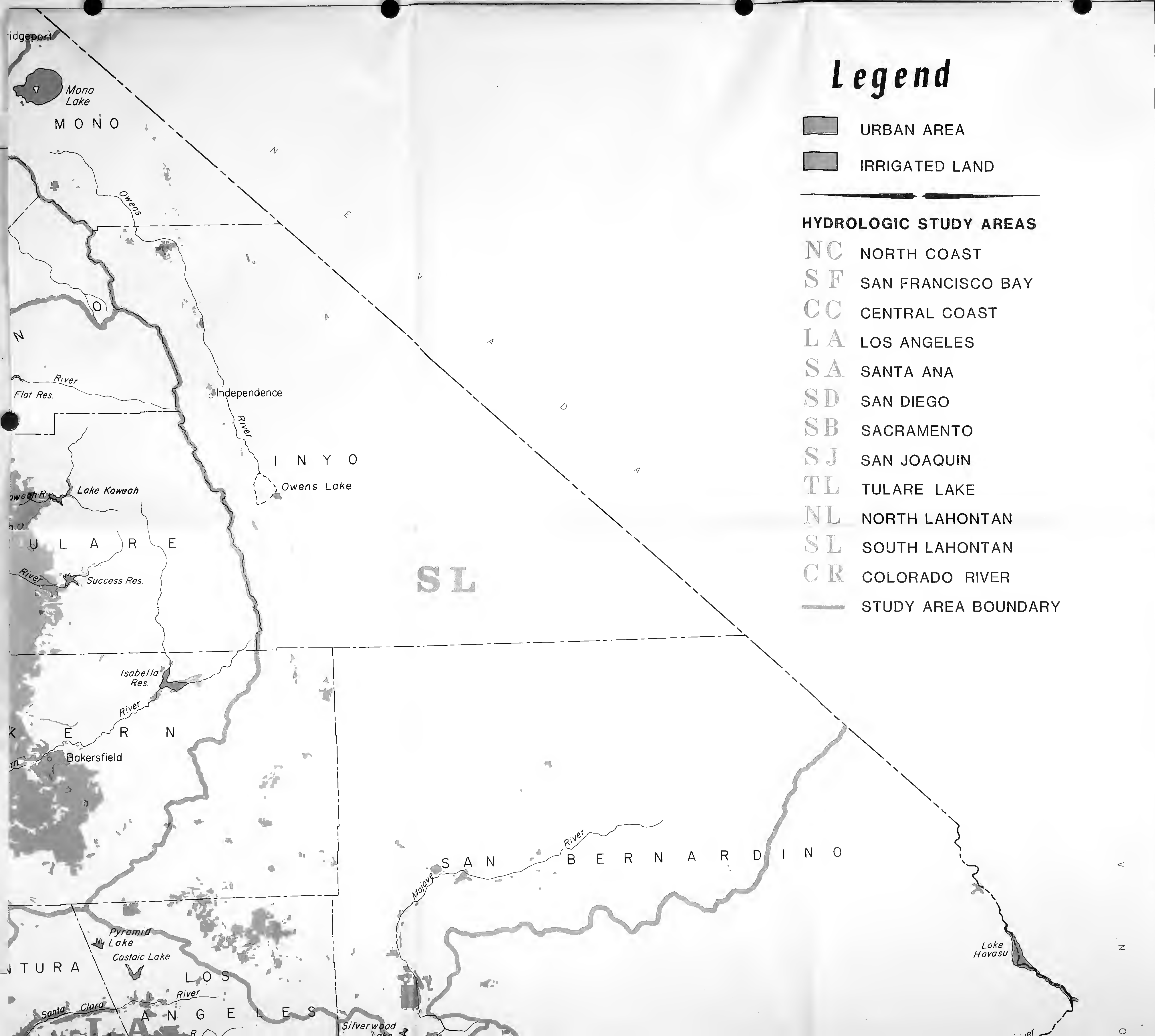
Department of Water Resources

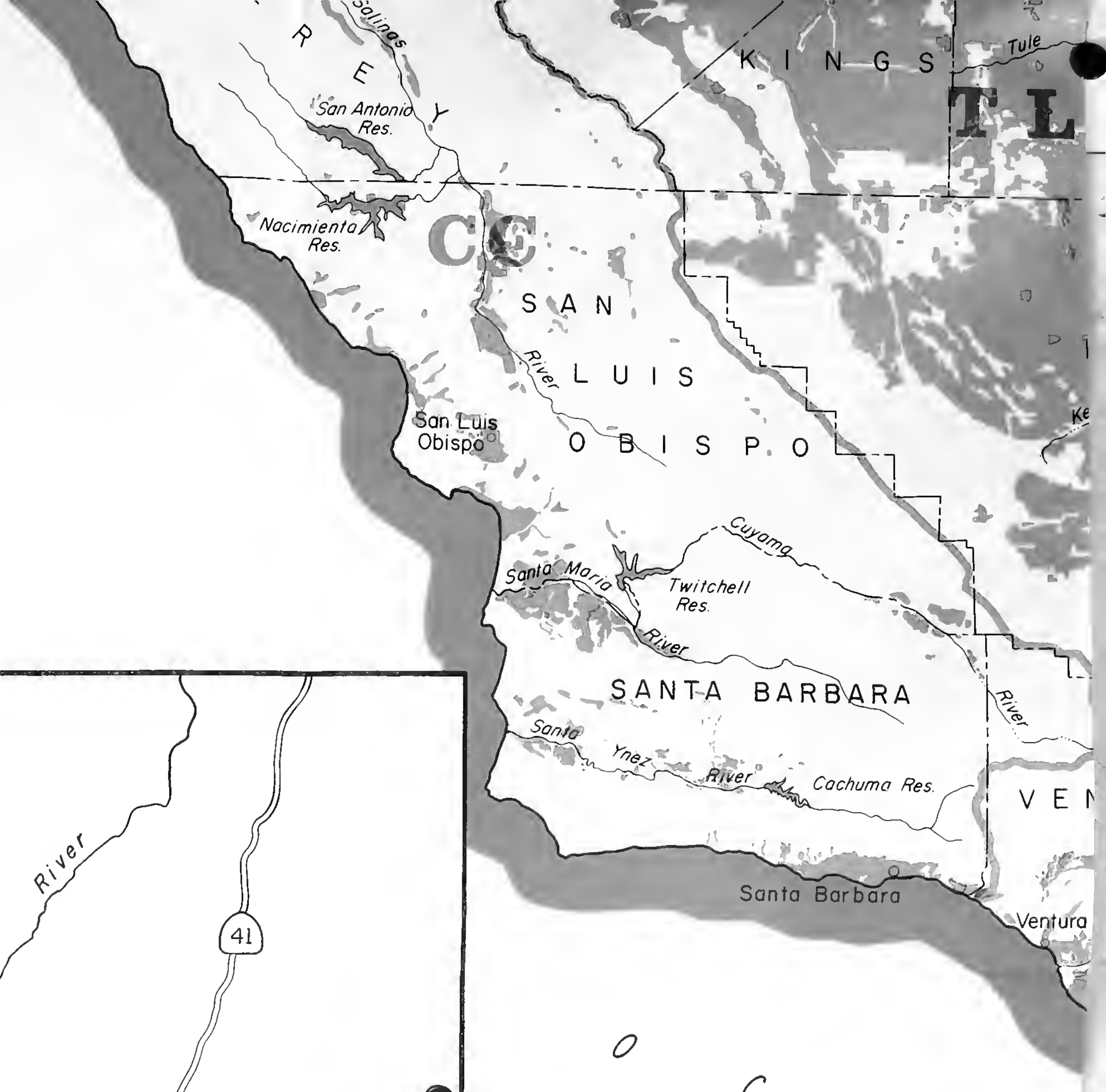
IRRIGATED AND URBAN LANDS

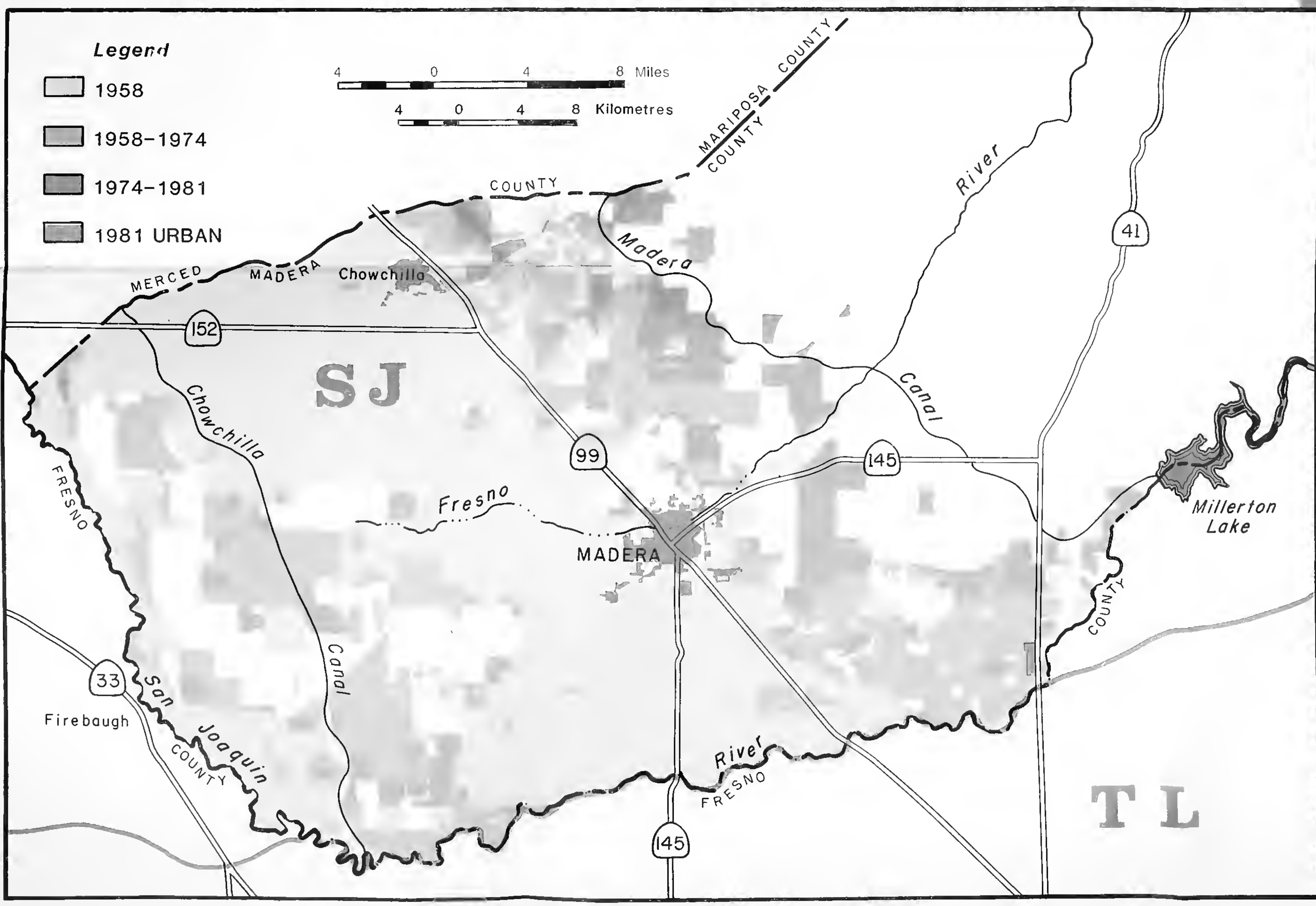


CHANGE IN IRRIGATED ACREAGE
GLENN COUNTY 1961 - 1981

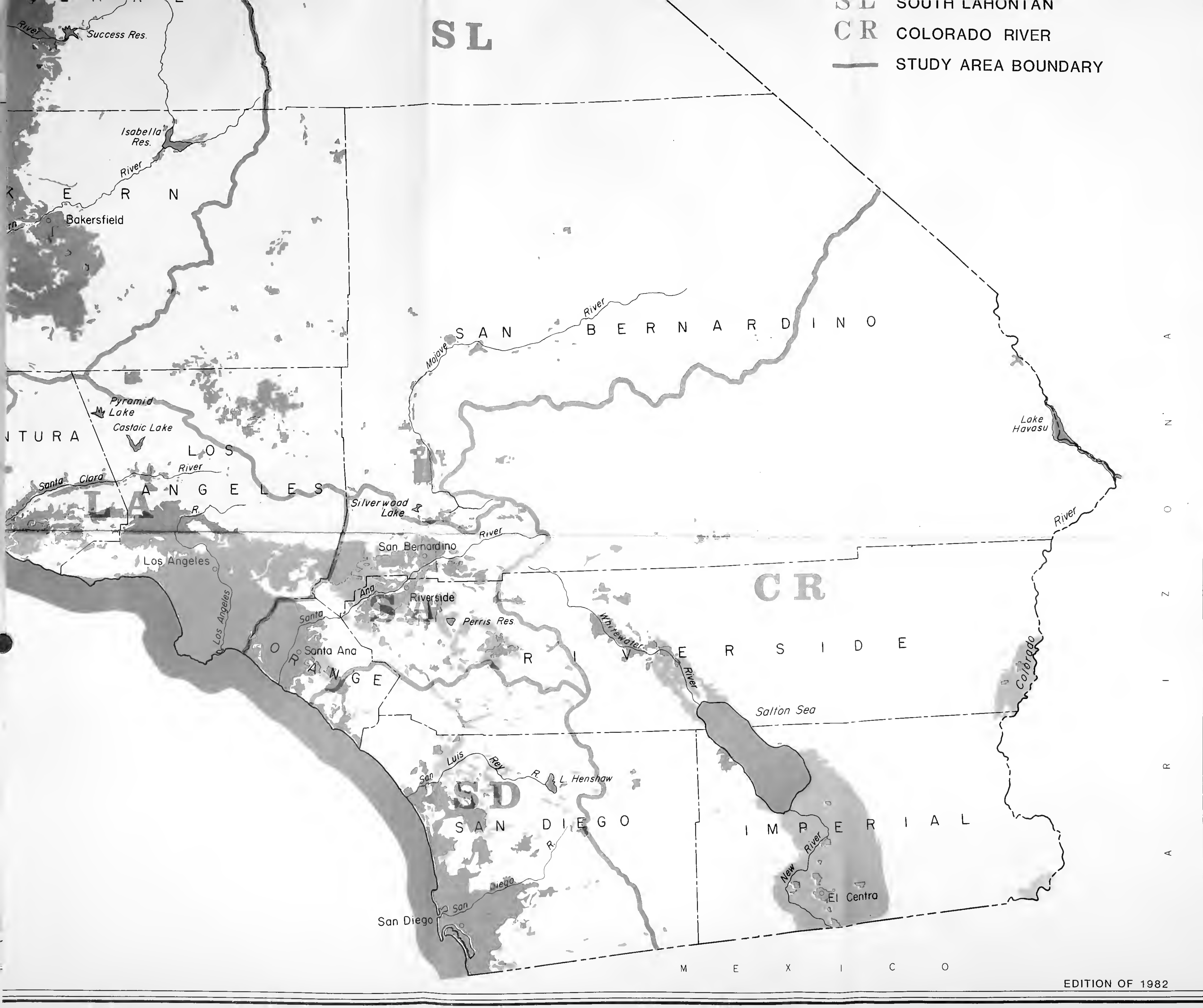

Legend
1958
1958–1974
1974–1981
4 0 4 8 Miles
4 0 4 8 Kilometres
MARIPOSA COUNTY
COUNTY
COUNTY
River
save water
DWR
N
SF
SJ
CC
TL
MARIN
SOLANO
Napa
Fairfield
San Rafael
Martinez
CONTRA COSTA
SAN FRANCISCO
Oakland
ALAMEDA
SAN MATEO
Redwood City
San Jose
SANTA CLARA
SANTA CRUZ
Santa Cruz
SAN JOAQUIN
Stockton
Comanche L.
Pardee Res.
Mokelumne
New Hogan Res.
San Andreas
CALAVERAS
Melanes Res.
River
Sonora
TUOLUMNE
River
Don Pedro Res.
Stanislaus
STANISLAUS
Modesto
Tuolumne
L. Mc Clure
River
MARIPOSA
Mariposa
Merced
MERCED
Merced
San Luis Res.
MADERA
Madera
Millerton L.
RIVER
Fresno
FRESNO
Kings
Pine
Hollister
SAN BENITO
Salinas
MONTEREY
Salinas
San Antonio Res.
Nacimiento Res.
Hanford
Visalia
KINGS
Tule
SAN LUIS OBISPO
River
San Luis Obispo
Cuyama
Santa Maria
Twitchell Res.
River
SANTA BARBARA
River
Santa
Ynez
River
Cachuma Res.
Santa Barbara
VEN


Legend
URBAN AREA
IRRIGATED LAND
HYDROLOGIC STUDY AREAS
NC NORTH COAST
SF SAN FRANCISCO BAY
CC CENTRAL COAST
LA LOS ANGELES
SA SANTA ANA
SD SAN DIEGO
SB SACRAMENTO
SJ SAN JOAQUIN
TL TULARE LAKE
NL NORTH LAHONTAN
SL SOUTH LAHONTAN
CR COLORADO RIVER
STUDY AREA BOUNDARY
SL
Mono Lake
MONO
Owens
NEVADA
Independence
River
INYO
Owens Lake
Lake Kaweah
Flat Res.
Success Res.
Isabella Res.
River
Bakersfield
SAN BERNARDINO
Mojave
River
Lake Havasu
Pyramid Lake
Castaic Lake
LOS ANGELES
Santa Clara
River
Silverwood





CHANGE IN IRRIGATED ACREAGE
MADERA COUNTY 1958 - 1981


SOUTH LAHONTAN
CR COLORADO RIVER
STUDY AREA BOUNDARY
SL
Success Res.
River
Isabella Res.
River
K E R N
Bakersfield
SAN BERNARDINO
River
Mojave
Pyramid Lake
Castaic Lake
NTURA
LOS ANGELES
River
Santa Clara
LA
R.
Silverwood Lake
San Bernardino
River
Los Angeles
Los Angeles
Santa Ana
Riverside
SA
Perris Res.
Santa
Santa Ana
ORANGE
RIVERSIDE
Whitewater
River
CR
Salton Sea
Lake Havasu
River
Colorado
ARIZONA
San Luis Rey R.
L. Henshaw
SD
SAN DIEGO
R.
San Diego
San Diego
IMPERIAL
New River
El Centro
MEXICO
EDITION OF 1982

O R E G O N
DEL NORTE
S I S K I Y O U
M O D O C
L A S S E N
S H A S T A
T R I N I T Y
H U M B O L D T
T E H A M A
P L U M A S
G L E N N
B U T T E
S I E R R A
NEVADA
M E N D O C I N O
L A K E
C O L U S A
Y O L O
S O N O M A
N A P A
SACRAMENTO
E L D O R A D O
A M A D O R
A L P I N E
P L A C E R
P A C
Crescent City
Lake Earl
Yreka
Lower Klamath L.
Tule L.
Meiss L.
Goose L.
Clear Lake Res.
Alturas
Allen Camp Res.
Lake Shastina
McCloud Res.
Iron Canyon Res.
Lake Britton
Enlarged Shasta Lake
Shasta L.
Keswick Res.
Clair Engle L.
Weaverville
Whiskeytown L.
Redding
Eureka
Butler Valley Res.
Dutch Gulch Res
Tehama Res.
Red Bluff
Eagle L.
Susanville
Lake Leavitt
Lake Almanor
Honey L.
Antelope L.
Dixie Refuge Res.
Abbey Bridge Res.
Quincy
Bucks L.
Lake Davis
Frenchman L.
Black Butte Res.
Lake Oroville
Downieville
Lake Pillsbury
East Park Res.
Sites Res.
Marysville Res
Nevada City
Lake Mendocino
Ukiah
Indian Valley Res.
Clear Lake
Lake Tahoe
Auburn Res.
Folsom L.
Placerville
Forni Res.
Sherman Res.
Watasheamu Res.
Markleeville
Alder Cr Res.
Lake Sonoma
Lake Berryessa
Woodland
West Sacramento Canal
New Spicer Meadow Res.
Middle Bar Res.
Jackson
Napa

State of California

Department of Water Resources

SURFACE WATER PROJECTS IN CALIFORNIA

Legend

EXISTING OR UNDER CONSTRUCTION

AUTHORIZED OR APPROVAL IN PROGRESS

RECENTLY EVALUATED OR UNDER STUDY

WILD AND SCENIC RIVERS

Scale in Miles

10 0 10 20 30 40 50

Kilometres

0 20 40 60

NOTE: EXISTING POWERPLANTS NOT SHOWN.

N

I F I C
O C E A N
Hood-Clay Canal
Camanche Res
Collierville Ph.
New Hogan Res
Delta Water Transfer Facilities
S O L A N O
Fairfield
Lake Chabot
Nicasio Res.
M A R I N
San Rafael
Martinez
CONTRA COSTA
Kellogg Res
Los Vaqueros Res.
Clifton Court Forebay
S A N J O A Q U I N
Stockton
T U O L U M N E
New Melones Res
Wards Ferry Res.
New Don Pedro Res
SAN FRANCISCO
OAKLAND
A L A M E D A
Lake Del Valle
San Antonio Res
Calaveras Res.
Modesto
S T A N I S L A U S
Lake McClure
M A R I P O S A
Mariposa
Redwood City
S A N M A T E O
SAN JOSE
S A N T A C L A R A
Merced
M E R C E D
O'Neill Forebay
Buchanan Res.
Hidden Res.
Millerton L
S A N T A C R U Z
Santa Cruz
San Luis Res.
Los Banos Grande Res.
Madera
Hollister
Little Panoche Res.
Castroville Pipeline
Hollister-Watsonville Conduit
Peninsula Pipeline
Salinas
East Side Pipeline
S A N B E N I T O
FRESNO
Mid - Valley
GOVERNOR
EDMUND
San Clemente Res. Enl.
Pool Res.
Arroyo Seco - Salinas Canal
M O N T E R E Y
Hanford
K I N G S
San Antonio Res
Nacimiento Res
Nacimiento Conduit
Branch
Coastal
S A N L U I S O B I S P O
San Luis Obispo
Lopez Res
Twitchell Res.
S A N T A B A R B A R A
Cachuma Res. Enl.
Salsipuedes Res.
Gibraltar Res. Enl.

Bridgeport
Mono L.
MONO
Lake Crowley
Granite Cr. Res.
Lake Edison
Huntington L.
Shaver L.
Courtright Res.
Wishon Res.
Dinkey Cr. Res.
Rogers Crossing Res.
Pine Flat Res.
Lake Sabrina
Tinemaha Res.
Independence
N E V A D A
I N Y O
Owens L.
AQUEDUCT
Bravo L. Res.
L. Kaweah
Visalia
T U L A R E
CANAL
Haiwee Res.
Lake Success
Lake Isabella
Kern Riv.
Bakersfield
K E R N
Buena Vista Lake Bed
LOS ANGELES
CALIFORNIA
Antelope Valley
Fairmont Res.
S A N B E R N A R D I N O
Pyramid L.
Castaic L.
Bouquet Res.
AQUEDUCT
V E N T U R A
Lake Casitas
L O S A N G E L E S
Mojave River Res.
Lake Havasu
Gene Wash Res.
Copper Basin Res.


KINGS
Tulare Lake Bed
EDMUND
San Antonio Res.
Nacimiento Res.
Nacimiento
Conduit
Branch
Coastal
Whale Rock Res.
SAN LUIS OBISPO
San Luis Obispo
Lopez Res
Twitchell Res.
SANTA BARBARA
Cachuma Res. Enl.
Salsipuedes Res.
Gibraltar Res. Enl.
OCEAN

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THE RESOURCES AGENCY